

Saskatchewan

A D F

Agriculture Development Fund

FINAL REPORT

19970283

**IMPROVING NURSERY PRODUCTION OF CONTAINER
GROWN HERBACEOUS PERENNIALS**

**Funded by
The Agriculture Development Fund**

**March 2002
Prepared by: Saskatchewan Nursery Trade Association**

FINAL REPORT

ADF #97000283

**Improving Nursery Production of Container Grown Herbaceous
Perennials**

FUNDED BY:

AGRICULTURE DEVELOPMENT FUND (ADF)

DUTCH GROWERS GARDEN CENTRE LTD.

LAKESHORE TREE FARMS LTD.

January 2002

Prepared by:

Erl Svendsen

Dr. Karen Tanino

Prepared for:

Saskatchewan Nursery Trades Association (SNTA)

685 Reid Rd.

Saskatoon, SK

S7N 3J4

Title

Improving Nursery Production of Container Grown Herbaceous Perennials

Project No:

ADF 97000283

Date of report completion:

January 19 2002

Principle investigator:

Tim Van Duyvendyk (president)

SNTA

685 Reid Rd.

Saskatoon, SK

S7N 3J4

Co-investigators:

i. Vic Krahm

Lakeshore Tree Farms Ltd.

Saskatoon, SK

ii. Karen Tanino

Dept. of Plant Sciences

University of Saskatchewan

51 Campus Dr.

Saskatoon, SK

S7N 5A8



Acknowledgements

Funding for this project was provided by the Agriculture Development Fund (ADF). We would like to thank our cooperators at Dutch Growers Garden Centre, Ltd. (Tim Van Duyvendyk, Rick Van Duyvendyk and Elsa Belyk) and Lakeshore Tree Farms, Ltd. for providing plant material, growing space, media & pots, and greatly appreciated advice. Finally, we would like to thank Bowman Greenhouses for providing a portion of the plant material used in the overwintering trials.

Improving Nursery Production of Container Grown Herbaceous Perennials

A. Summary

The nursery industry is one of the most rapidly growing sectors of the horticulture industry. Demand for quality perennials has grown tremendously in the last few years. Small (immature) perennials may require 2 or 3 growing seasons in a landscape to achieve their full potential and so may frustrate many consumers' desire for an 'instant' garden. These same consumers are likely willing to purchase larger, more mature specimens. Growers need to develop and/or adopt techniques that will enable them to grow larger perennials in a relatively short period without substantially increasing production costs. A number of trials were initiated to address fertility, weed control, media and irrigation concerns. Overwintering trials were conducted with rooted cuttings to assess optimal container size for maximum survival rate.

B. Executive Summary

Consumer demand for larger herbaceous perennials is growing and producers are hard-pressed to keep up with demand while keeping retail and wholesale prices at a reasonable level.

Saskatchewan-grown perennials are typically greenhouse-produced, either from seed or from cuttings. These perennials are produced for sale in the current or early next season and are typically small and not able to capture 'top' dollar. In order to supply larger and more mature plants, most growers rely on out-of-province production of bare-root, rooted cuttings or large seedlings ready for potting up and growing on from February to April for current season sales. This means that plants are produced at times when fuel and energy costs are at a premium. There are also associated problems of growing plants in greenhouses (e.g. crop failure due to furnace breakdowns, disease problems, low natural light levels requiring supplemental light source, etc.). These factors contribute to elevated production costs, making it difficult for Saskatchewan nursery growers to produce plants economically enough to compete against growers in other production regions in Canada or the US. In fact, outside growers can supply a product that can retail in Saskatchewan for less than what Saskatchewan growers can produce it for.

One of the largest problems that Saskatchewan growers face is the great difficulty in overwintering plants while they are still in their containers. Developing outdoor container-production management techniques would reduce the cost of production. Further, by optimizing fertility, water and weed management practices, growers should be able to then produce herbaceous perennials at a cost that would allow them to compete effectively with out-of-province growers.

Eight trials were completed that addressed media, fertility, irrigation, container size, weed control and storage issues. Also, nearly 100 perennial production research and extension articles were added to the Nursery Production Literature Collection (NPLC) housed at the Dept. of Plant Sciences.

#1: Media

Commercial premixed soil-less medium is the standard in herbaceous perennial production but represents a significant cost. One of the aims of this project was to reduce the cost of production and replacing the commercial premixed media with a lower-cost alternative would accomplish this. In total, 6 soil-less media were evaluated at both cooperator sites. *Echinacea* performed equally well in Sunshine #4 (commercial mix), 100% coarse peat and the standard site media from both cooperators. *Salvia* performed best in Sunshine #4 and 100% coarse peat. Since 100% coarse peat is much cheaper than Sunshine #4, performs as well as Sunshine #4, and is available in bulk, growers should consider introducing 100% peat into their herbaceous perennial production system.

#2: Fertility

Two aspects of fertility were evaluated: nitrogen rate and nitrogen source.

Nitrogen rate: In two of the three years, plant (*Liatris*, *Helenium*, *Echinacea* and *Salvia*) growth increased as fertilizer levels increased but in less than a one-to-one relationship (i.e. doubling fertilizer rate did not necessarily double plant size). The moderate fertilizer rate (1.2 kg N/m³ media) used in this project represents a good compromise between maximizing plant growth, avoiding salt damage and minimizing costs.

Nitrogen source: Controlled release fertilizer is the most typical fertilizer form used in commercial nurseries and are in two basic forms: encapsulated and non-encapsulated. Of the three species (*Heliopsis*, *Eupatorium* and *Liatris*) grown in 1999, only *Heliopsis* was affected and growth was best in Nutricote and Osmocote (both encapsulated forms). In 2000 and 2001, Osmocote (encapsulated) and Apex (non-encapsulated) were equivalent in terms of *Echinacea* and *Salvia* growth. When differences in plant productivity existed among fertilizer source treatments, both Apex and Osmocote consistently produced superior plants.

#3 Irrigation:

The two cooperators have distinctly different irrigation philosophies: one grower uses pulse irrigation (3 – 5 short irrigation events throughout the day controlled with an electronic timer) and the other cooperator, cyclic irrigation (1 or 2 long irrigation events manually controlled). Irrigation was not quantitatively evaluated but significant differences in plant productivity in both *Echinacea* and *Salvia* treatments existed between sites when identical treatments (media and plant species) were compared. In 2000, Dutch Growers was the superior site whereas in 2001, Lakeshore was the superior site. The difference can be attributed to the care that was taken in adjusting the irrigation to the time of year and temperature. This argues that irrigation management must be fine-tuned throughout the growing season in favour of plant productivity rather than convenience or water conservation whether an electronic timer is used or not.

#4 Container Size:

In general, when starting the with same size plant, the larger the container the larger the finished plant. In practice there was a consistent increase in plant size (*Nepeta*, *Coreopsis*, *Echinacea* and *Salvia*) as container size increased from 55 J Deep (1350 mL) to 1 gallon (2200 mL) with mixed results when container size was extended to 2 gallon (5560 mL). This provides a good argument that growers should start their initial plant

material (whether it be plug, rooted cutting, bare-root, etc.) in its finished container size upto 1 gallon (2200 mL). The larger container may take up more resources (space, media, fertilizer, water) initially, but the time required to reach a saleable size is considerably reduced.

#5: Weed Control

Only rice hulls, used as a top-dressed weed controlling mulch, provided a consistently high weed control level at both cooperator sites in 2000 and 2001. The pre-emergence herbicides, while not affecting plant growth in any years, did not provide consistent nor season-long control. Where significant differences existed [with only one exception (*Campanula*, 2000 @ Lakeshore Tree Farms)], plant growth in the rice hulls treatment was higher than in control for *Echinacea*, *Salvia*, *Veronica* and *Campanula*. Obtaining a supply of rice hulls from the North (wild rice production area) remains a challenge.

#6: Storage

The smaller the container, the less buffered the root zone is against changes in storage temperatures. Outdoor air temperature has the largest effect on root zone temperatures; but once snow cover is established, this effect is reduced. Except for three days in February 2000 at Dutch Growers, storage temperatures were $> -10^{\circ}\text{C}$. Plant survival was inconsistently affected by container size; a confounding affect was the incidence of storage disease in at least one species. After survival was assessed, plants were potted up into a common container size. Following two months of regrowth, where significant differences existed (i.e. *Artemesia*, *Echinacea*, *Gentiana*, *Penstemon*, *Stachys* and *Thymus*), plants overwintered in large containers were larger than those overwintered in small containers. This last observation leads to the recommendations that perennials can be potted up into their final container size in the early fall (thus avoiding the busy spring season when labour is a premium), grown on until freeze-up and overwintered. In future, the use of a prophylactic fungicide spray to reduce the mortality of susceptible species (e.g. *Gentiana* and *Lamium*) should be investigated.

#7: Media fertility evaluation

In 1999, an attempt was made to correlate leachate parameters (pH, EC, NO_3^- , and K^+) that a grower could easily assess himself to actual fertility levels. EC was an excellent ($r^2 > 0.85$) predictor of nitrate and potassium levels in leachate extractions of ground media. The EC of whole-media-leachate was not as good a predictor of nitrate and potassium levels, but still provided a reasonable prediction ($r^2 = 0.70$). More work is required in this area to develop recommendations and link measured parameters to container fertility level.

#8: Literature Collection

The Nursery Production Literature Collection (NPLC), is a collection of over 1200 research and extension articles, managed using an electronic database manager, making searches and access relatively easy and quick. This collection was begun with ADF #95000327 (Improving nursery production of field and container grown woody ornamentals) and has continued to grow with each new project. In this project, an additional 96 articles have been added to the database. This database is available to growers, researchers, students and other interested parties.

Table of Contents

Acknowledgements	ii
A. Summary	iii
B. Executive Summary	iii
C. Technical Report	1
Media, Fertilizer and Irrigation	2
Trial #1: Media comparison, fertilizer source and irrigation management	2
Trial #2: Determine optimum container size for herbaceous perennial production (large mature plants)	16
Trial #3: Determine optimum fertilizer rate for container production of herbaceous perennials	22
Trial #4: Evaluate the effect of fertilizer source (manufacturer and formulation) on growth of containerized herbaceous perennial plants	28
Trial #5: To determine optimum medium porosity characteristics suitable for container production of herbaceous perennial plants (2000 – 2001).....	34
Weed Control.....	40
Trial #6: Evaluation of chemical and non-chemical weed control in containerized herbaceous perennials	40
Storage	52
Trial #7: Evaluation of container size and storage location on herbaceous perennial winter survival.....	52
Fertility Assessment	70
Trial #8: Media fertility assessment	70
Perennial Literature Collection.....	89
D. Extension Activities	149
E. Further Development	149
F. Personnel.....	149
G. Equipment.....	149

C. Technical Report

Project Objectives:

Consumers are demanding larger and better quality herbaceous perennials. In order to supply this demand, retailers are importing plants from BC, Ontario and the US as local growers have been unable to produce a larger product at reasonable cost. The main objective, therefore, is to provide growers with the tools necessary to compete with out-of-province producers on both quality and price. In order to do this, current fertility, media, irrigation, weed control and over-wintering management strategies for woody ornamentals will be evaluated for their suitability for perennial production. Furthermore, perennial specialists at both Dutch Growers Garden Centre and Lakeshore Tree Farms (two of the largest grower/retailers in the province) were consulted to identify: which species were considered 'problem' crops in terms of slow growth, production issues inherent in perennial production (media, fertility, production, etc.) and determine which what species were difficult to over-winter successfully. To develop an information resource for growers, a literature collection on perennial crops was created.

Media, Fertilizer and Irrigation

Trial #1: Media comparison, fertilizer source and irrigation management

Water availability has the largest impact on plant growth of all the environmental factors during the growing season. Mild drought may not lead to any visual symptoms such as wilting, but growth will certainly be affected (i.e. reduced). One of the strategies that plants have in dealing with drought is to shut their stomata, thus protecting themselves against further water loss. While the stomata are closed, plants no longer have a cooling mechanism leading to overheating, are unable to take in carbon dioxide and take up soil nutrients. Consequently no growth occurs. Prolonged drought can disrupt critical physiological processes and destroy cells and plant organs to the point that plants may not be able to recover. Conversely, if too much water is supplied, roots may die from oxygen starvation (anoxia). Fewer roots mean that a plant is unable to supply its above ground portion with adequate water and nutrients possibly leading (ironically) to drought-like conditions. Too moist a growing medium can also lead to the development of plant disease (bacterial and fungal), further reducing plant health and quality. Also, while the release rate of most controlled release fertilizer is strongly influenced by temperature, excess irrigation will lead to increased leaching and thus reduce the expected product longevity.

The two main factors that affect water availability are irrigation frequency & volume and water holding characteristics of the media.

In the ideal irrigation scheme, water would be supplied just before plants begin to suffer from drought and only enough water would be supplied to bring the medium up to field-capacity with minimum leaching. In the real world, this scheme is impractical, as many species are typically grown together each with their own water requirements. Indeed, no two plants will have the identical water requirements. Also the warmer the temperature and the higher the light intensity, the higher the surface evaporation and evapotranspiration, and consequently a plant's water requirement also increases. Growers must therefore juggle the need to supply only enough water to meet plant requirements (conservation) and the need to avoid drought conditions (preservation). Most growers avoid drought conditions by over-supplying water and irrigate using a seasonally adjusted schedule. There are two popular methods of supplying water: cyclic (one or two long [30

– 45 min] irrigation events per day) and **pulse** (3 or more short [5 – 15 min] irrigation events per day).

Grower-medium can be composed of a number of components, but all media will have measurable pore (empty) space. The pore spaces will either hold air or water and a plant's roots require both. At field capacity, this pore space will be divided between aeration porosity (AP) and water holding capacity (WHC). WHC is the water that the medium in a container can hold against gravity at field capacity and will be relatively constant over a growing season. The consequence is that once a container is at field capacity, excess water will simply flow out of the container. Also, while two media may have the same total pore space, one may have a higher WHC relative to AP while for the other the reverse may be true. A medium with high WHC does not need to be irrigated as frequently as the other medium with low WHC. If the medium with high WHC is irrigated too frequently, insufficient air will be left in the root zone, leading to anoxia. On the other hand if the medium with low WHC is not irrigated frequently enough, plants may experience mild to severe drought. The bottom line is that medium porosity characteristics should be matched to irrigation scheme and when one factor is changed, the other should be re-evaluated and adjusted as necessary.

This series of experiments evaluated plant performance grown in a variety of media under two irrigation schemes in one container size.

1999 [media evaluation]

Objective:

To evaluate the plant growth in two media under one irrigation scheme

Materials & Methods

Site:

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm (**cyclic**)

Media:

LS-Standard woody ornamental medium (65% sawdust + 25% peat + 10% sharp Bermuda sand + standard fertilizer amendments)

Premier Pro-Mix BX (peat + perlite + 1.2 kg N/m³)

Species:

Coreopsis verticillata 'Moonbeam' (bare-root)

Liatris spicata (corm)

Veronica longifolia 'Sunny Border Blue' (Etera container) [this species was severely affected by Aster Yellows (*Chlorogenus callistephi*) and was removed from the trial]

Plants were potted up in 2.73 litre nursery containers on May 10, 1999 at Lakeshore Tree Farms Ltd. and were placed out in the woody ornamental production area. Plants were harvested on September 16, 1999.

Number of main stems and above ground fresh and dry weights were recorded. There were five replicates with one plant per replicate for each treatment and species. Plants were arranged in a Completely Randomized Design (CRD) within each species. Data was tested with ANOVA and LSD (Fisher's protected) was used to separate means whenever $p \leq 0.05$.

1999 [irrigation, media and fertilizer source]

Objective

To evaluate plant growth in two media, two irrigation schemes and three nitrogen sources

Materials & Methods

Sites and irrigation scheme:

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm (pulse)

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm (cyclic)

Media:

DG-Standard woody ornamental medium (70% composted bark chips + 30% peat)

LS-Standard woody ornamental medium (65% sawdust + 25% peat + 10% sharp Bermuda sand)

Fertilizer:

Nutricote 18-6-8 Type 100 (NC)

WoodAce 21-4-10 (WA)

HighN 19-5-8 (HighN)

(fertilizer rate: $1.2 \text{ kg N/m}^3 = 2 \text{ lb N/yd}^3$)

Species:

Heliopsis scabra

Eupatorium purpureum 'Atropurpureum'

Liatris spicata

All species were grown with all fertilizers and in both media. *H. scabra* was grown at both sites, *E. purpureum* at Dutch Grower only and *L. spicata* at Lakeshore only. Plants were potted up in 2.73 litre nursery containers on May 6, 1999 at Dutch Growers Garden Centre Ltd. and on May 10, 1999 at Lakeshore Tree Farms Ltd. and were placed out in the respective woody ornamental production areas.

At the end of the season, the number of main stems and above ground fresh and dry weights plants were recorded. There were four replicates with two plants per replicate for each treatment and species. Plants were arranged in a Completely Randomized Design (CRD) within each species. Data was be tested with ANOVA and LSD (Fisher's protected) was used to separate means whenever $p \leq 0.05$.

2000 [irrigation and media evaluation]

NOTE: The number of species was reduced in the 2000 trials to accommodate increased replicates as an attempt to reduce experimental variability. Therefore, the species and plant source used in 1999 were not used in subsequent trials.

Objective

To evaluate plant growth in three media and two irrigation schemes

Materials & Methods

Site (irrigation scheme):

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm (pulse)

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm (cyclic)

Media:

DG medium (70% composted bark chips + 30% peat)

LS medium (65% sawdust + 25% peat + 10% sharp Bermuda sand)

Sunshine #4 (peat + perlite commercial greenhouse mixture)

[all media were amended with 1.2 kg N/m³ = 2.0lb N/yard³ medium with Osmocote Pro 22-3-8; each container was amended individually: no bulk mixing]

Species:

Echinacea purpurea 'Bright Star' (seedling)

Salvia nemorosa 'Mai Nacht' (cutting)

Perennials were purchased from Bowman Greenhouses (BC) as 128-plug cell rooted cuttings. Plants were received on June 22 2000 and transplanted into 2.73 litre nursery containers (Lerio #010). *Echinacea* was received in good condition; *Salvia* was not. Shipment had been held for 1 week at distributor and this resulted in loss of quality due mainly to disease (Figure 1-1). There were 10 replicates of 3 plants/per replicate (2 sites x 3 media types x 10 replicates x 3 plants/replicate = 180 plants) for *Echinacea* and 8 replicates of 3 plants/per replicate (2 sites x 3 media types x 8 replicates x 3 plants/replicate = 144 plants) for *Salvia*. Treatments were arranged in a Completely Randomized Design (CRD). Number of stems, crowns, fresh weight and dry weight data (as appropriate for each species) was collected on Sept. 1 2000. Data was analyzed with ANOVA and treatment means were compared with LSD (Fisher's protected).

2001 [irrigation and media evaluation]

Objective:

To evaluate plant growth in six media and two irrigation schemes

Materials & Methods

The 2000 trial was expanded, using the same species, to include 100% peat, DG-Standard medium (dg medium + DG-Standard amendments), and LS-Standard medium (ls medium + LS-Standard amendments) at both sites. Also, the fertilizer level used in 2000 was reduced in 2001 (to $0.6\text{kg N/m}^3 = 1.5\text{ lb/yd}^3$ from $1.2\text{ kg N/m}^3 = 2.0\text{ lb N/yd}^3$) based on 2000 fertility trial results (see Trial #3)

Plants were received from Bowman Greenhouses (BC) as 128 plug seedlings. They were potted up at Dutch Growers on June 11 & 12 and at Lakeshore on June 14 & 15. There was 10 replicates of 3 plants/per replicate (2 sites x 6 media types x 10 replicates x 3 plants/replicate = 360 plants). Treatments were arranged in a Completely Randomized Design (CRD). Number of stems, crowns, fresh weight and dry weight data (as appropriate for each species) was collected on Sept. 11 – 14, 2001. Data was analyzed with ANOVA and treatment means were compared with LSD (Fisher's protected).

Results & Discussion

1999

Both *liatris* and *coreopsis* performed better in the commercial medium than in LS-Standard medium. Dry weight was significantly ($p \leq 0.05$) higher when grown in ProMix BX (175 and 203% higher in the case of *liatris* and *coreopsis*, respectively) (Table 1-2). This result is likely due to favourable porosity characteristics of the commercial medium under LS irrigation management (Table 1-1).

Heliopsis, the only species evaluated at both sites, had significantly ($p \leq 0.01$) higher dry weight when grown at DG compared to LS. Both sites are in close proximity, in full sun and enjoy protection from wind and so the major difference between these growing areas is irrigation management. At DG, irrigation occurs throughout the day (3 – 5 times depending on season) and so on the hottest days, drought stress is less likely to occur (irrigation events 2 – 3 hours apart). At LS, where irrigation occurs in the morning and again at the end of day (5 – 7 hours later), drought stress leading to reduction in plant growth and vigor may occur (Table 1-3).

Eupatorium (only at DG) was unaffected by medium. Heliopsis (both) had significantly ($p \leq 0.01$) higher dry weight when grown in DG medium; Liatris (only at LS) had significantly higher dry weight ($p \leq 0.01$) and stems ($p \leq 0.05$) when grown in DG medium (Table 1-3). The main difference between the two media is the water holding capacity (WHC) with DG media having 44.5% and LS, 35.5% (Table 1-1). This additional WHC would result in a lower chance of drought stress and a slightly lower leaching fraction. This latter fact would mean that less fertilizer might be lost.

2000 & 2001

Site comparison

2000: Echinacea dry weight was significantly ($p \leq 0.01$) higher at DG but salvia dry weight was significantly higher ($p \leq 0.05$) when grown at LS. The reverse was true for stem counts, where there were significantly ($p \leq 0.05$) more echinacea stems produced at LS and significantly ($p \leq 0.01$) more salvia stems produced at DG (Table 1-4).

2001: In contrast to 2000, Echinacea growth (dry weight, number of crowns and number of stems) was significantly higher ($p \leq 0.01$ for all characteristics) at LS than at DG (Figures 1-1 and 1-2). Salvia growth, as in 2000, was significantly higher at LS than at DG (Figures 1-3 and 1-4) (Table 1-4).

Irrigation management was the most influential factor that differed between sites. Irrigation at DG is controlled with an automatic timer; at LS, irrigation is controlled manually. In 2000, irrigation management at DG, adjusted throughout the season for changes in temperature, led to superior growth of echinacea. An employee who had a number of other duties managed irrigation at LS, and drought stress occurred occasionally resulting in reduced growth. In 2001, irrigation scheduling at DG late in the season was not adjusted when the weather cooled, and irrigation continued as if it were early August. This led to overwatering (leaching) and excess humidity (root and stem rot) and both these conditions reduced the potential growth. At LS in 2001, an employee whose only duty was irrigation management carefully monitored water needs over the entire season, making adjustments as required. Growth was therefore optimized under these latter

conditions. To illustrate this point further, echinacea growth in Sunshine #4 medium was nearly double at LS compared to DG.

Media comparison

2000: Echinacea growth was significantly affected by media, where the best ($p \leq 0.01$) growth in terms of number of stems and dry weight occurred with Sunshine #4 media and the highest ($p \leq 0.01$) number of crowns in DG media. There was also significant growing location x media interaction for all three measured echinacea characteristics. The interaction is a result of the significant reduction in growth in LS medium at LS. Echinacea dry weight was equivalent to the best treatment in LS media at DG and significantly lower than all other treatments at LS. The number of stems and crowns were similarly affected. Salvia growth was unaffected by media and there were no growing location x media interactions (Table 1-4).

2001: Sunshine #4, 100% peat, LS-Standard, and DG-Standard media yielded equivalent growth in Echinacea and these media were significantly better ($p \leq 0.01$ for number of stems, number of crowns and dry weight) than the remaining media types. All were significantly ($p \leq 0.01$) better than LS medium (NOTE: LS medium is NOT the same as LS-Standard) (Figures 1-1 and 1-2). Salvia performance was similar but with a few important differences. The number of stems produced in Sunshine #4 medium was equivalent to 100% peat and both produced a significant ($p \leq 0.01$) greater number than all other media. There were significantly ($p \leq 0.01$) fewer stems produced in LS medium (see note, above) than all other media. Salvia dry weight was highest in DG-Standard and 100% peat and both were significantly better than all other media. LS medium was again the poorest performer in terms of dry weight (Figures 1-3 and 1-4) (Table 1-4).

There were significant growing location x media interactions for both echinacea and salvia. This was a result of changes in relative performance ranking of media between sites. In the case of echinacea, DG-Standard and DG media performed relatively better at DG than at LS (dry weight); LS-Standard relatively better at LS than at DG (stems); 100% peat relatively better at DG than LS (stems); and Sunshine #4 medium relatively better at LS than DG (crowns). For salvia, dry weight was more affected than number of stems: 100% peat was the best performer at DG whereas DG-Standard was the best at LS (dry weight); Sunshine #4 medium performed relatively better at LS

than at DG (dry weight); and LS-Standard performed relatively better at LS than at DG (stems) (Table 1-4).

The main difference among media in 2000 was porosity since all media were amended with the same fertilizer levels and fertilizer source. Results can be explained if each location is considered separately. At DG, both LS and Sunshine #4 media performed equally well and both were better than DG medium. LS and Sunshine #4 media have similar water holding capacity (WHC) and much higher than DG medium. High WHC would reduce the chance of drought stress, thereby maximizing growth potential. At LS, this same high WHC could have lead to anoxic conditions (i.e. low root oxygen levels), thus reducing growth potential in LS media. It would seem that slightly less WHC, as in the case of Sunshine #4 medium, was enough to prevent growth reduction. Difference in performance between salvia and echinacea can be attributed to differences in moisture requirements/tolerance.

In 2001, with the introduction of additional media to this trial, interpretation is somewhat more complex. LS medium was in general a very poor performer compared to all treatments and to 2000 results. The difference between the two years was that different people mixed the base medium (without fertilizer). While porosity characteristics were similar, 2001 LS medium had a higher WHC than 2000 LS medium; furthermore, 2001 LS medium had the highest WHC of all media tested in 2001. This may have been enough by itself to significantly reduce growth.

Bulk peat was equal in most cases to the more expensive Sunshine #4 medium in terms of maximizing growth potential. DG-Standard and LS-Standard were also good performers. This taken together would suggest that any of the three (bulk peat, DG-Standard or LS-Standard) could be used as suitable herbaceous perennial medium. It is interesting to note that while DG-Standard performed well, its WHC was considerable lower than any of the other three top media.

Summary

Two main points can be taken from this study. First, irrigation management must be fine tuned to meet a plant's changing needs over the season, taking into account both changes in temperature and changes in plant size. If this is done consistently well over the season, growth potential will be maximized. The second point is that a number of media performed well. The grower needs to

evaluate what is the most economical medium in their situation. In this study, 100% peat performed just as well as the commercial premixed medium. The standard site media also performed well. Since the standard site medium is prepared in any event, it may be the easiest to use just one media for all applications.

Table 1-1. Media Porosity Characteristics

Media	Container Size (L)	Total Porosity	Aeration Porosity	Water Holding Capacity
Dutch Grower medium	1 gal (2.50)	74.2	34.3	39.0
Dutch Grower-Standard	1 gal (2.50)	71.6	32.3	39.3
Sunshine #4	1 gal (2.50)	65.8	14.7	51.1
Lakeshore medium	55 J D (1.40)	74.0	22.0	52.0
Lakeshore medium	15 cm (1.48)	72.7	23.2	49.5
Lakeshore medium	1 gal (2.50)	78.2	24.6	53.6
Lakeshore medium	2 gal (5.60)	59.4	24.5	34.9
Lakeshore-Standard	1 gal (2.50)	80.8	29.2	51.7
100% peat	1 gal (2.50)	81.1	31.7	49.4
75% peat + 25% bark	1 gal (2.50)	80.0	37.8	42.2
25% peat + 75% bark	1 gal (2.50)	80.3	42.7	37.6
100% bark	1 gal (2.50)	87.0	47.0	40.0

Table 1-2. *Liatris* and *Coreopsis* growth in two media grown at Lakeshore Tree Farms over the 1999 growing season

Media	<i>Liatris</i>		<i>Coreopsis</i>	
	stems	dw (g)	stems	dw (g)
ProMix BX	2.8	45.9	32.5	26.9
Lakeshore-Standard	1.4	26.1	21.6	13.2
Statistical Analysis				
Significance [†]	ns	*	+	*
LSD	-	19.6	10.0	10.7
CV%	92.2	33.5	29.1	30.9

[†]: ns = not significant; +, * = significant at $p \leq 0.10$ and 0.05 , respectively

Table 1-3. Heliopsis, Eupatorium and Liatris growth response to growing site, media and fertilizer source (1999)

source (1999)			Heliopsis		Eupatorium		Liatris	
Location	Media	Fertilizer	stems	dw (g)	stems	dw (g)	stems	dw (g)
Lakeshore	DG medium	Nutricote	3.2	22.5			3.5	30.4
		Osmocote	3.5	19.9			3.9	29.7
		WoodAce	3.0	16.9			4.1	29.5
	LS medium	Nutricote	2.7	18.3			2.5	18.1
		Osmocote	2.2	16.9			2.1	25.9
		Wood Ace	2.3	12.2			2.4	25.0
Dutch Growers	DG medium	Nutricote	3.1	46.7	6.0	45.9		
		Osmocote	3.3	28.7	4.1	37.0		
		Wood Ace	6.2	43.8	2.8	31.2		
	LS medium	Nutricote	3.7	37.8	3.4	44.9		
		Osmocote	3.0	24.3	2.2	40.8		
		Wood Ace	2.0	22.3	2.0	37.2		
Statistical Analysis								
Significance [†]	Location (L)		ns	**				
	Media (M)		ns	**	ns	ns	*	**
	Fertilizer (F)		ns	**	ns	ns	ns	ns
	F x M		ns	ns	ns	ns	ns	ns
LSD	L		-	6.6				
	M		-	6.3	-	-	1.1	5.8
	F		-	7.7	-	-	-	-
	F x M		-	-	-	-	-	-
CV%			40.9	38.0	81.6	37.2	44.4	18.7
† - ns and * ** = not significant and significant at p ≤ 0.05 and 0.01, respectively								

[†] - ns and *, ** = not significant and significant at $p \leq 0.05$ and 0.01 , respectively

Table 1-4. The effect of media and location (irrigation management and water quality) on the growth of Echinacea and Salvia

Location	Media	Echinacea				Salvia			
		2001		2000		2001		2000	
		stems	crowns	dw (g)	stems	stems	dw (g)	stems	dw (g)
Lakeshore	100% peat	0.40	4.67	17.25	0.93	7.03	15.20	4.63	10.07
	DG medium	0.13	4.10	9.93		4.93	11.51		
	DG-Standard	0.43	4.90	15.21		7.43	16.17		
	LS medium	0.00	1.93	2.63	0.32	1.82	4.91	3.90	8.92
	LS-Standard	0.83	4.97	17.14		6.80	14.29		
Dutch Growers	Sunshine	0.70	6.13	19.32	2.03	8.57	15.60	4.04	7.63
	100% peat	0.20	4.03	10.56		6.17	11.04		
	DG media	0.03	3.60	9.94	0.63	4.20	9.42	5.32	7.30
	DG-Standard	0.10	4.38	10.99		3.87	9.83		
	LS medium	0.03	1.75	1.92	0.88	1.33	2.65	4.69	6.95
Statistical Analysis	LS-Standard	0.13	3.15	9.77		5.20	9.32		
	Sunshine	0.28	3.67	10.46	0.68	5.58	8.10	6.50	6.43
	Location (L)	**	**	**	*	**	**	**	*
	Media (M)	**	**	**	**	**	**	ns	ns
	L x M	**	**	**	**	**	**	ns	ns
LSD	L	0.14	0.64	1.79	0.32	0.69	1.36	1.07	1.81
	M	0.25	0.69	2.28	0.44	1.03	1.49	-	-
	L x M	0.35	0.98	3.22	0.62	1.46	2.11	-	-
CV%	L	21.4	30.8	30.2		24.96	24.21		
	M, L x M	23.6	21.1	24.4	55.7	23.71	16.77	33.2	35.5

† - ns = not significant, * = significant at $p \leq 0.05$ and $p \leq 0.01$, respectively



Figure 1-1. Echinacea growth in various media (2001). A. DG-grown plants, B. LS-grown plants. From left to right: LS medium, LS Standard, DG medium and DG standard.

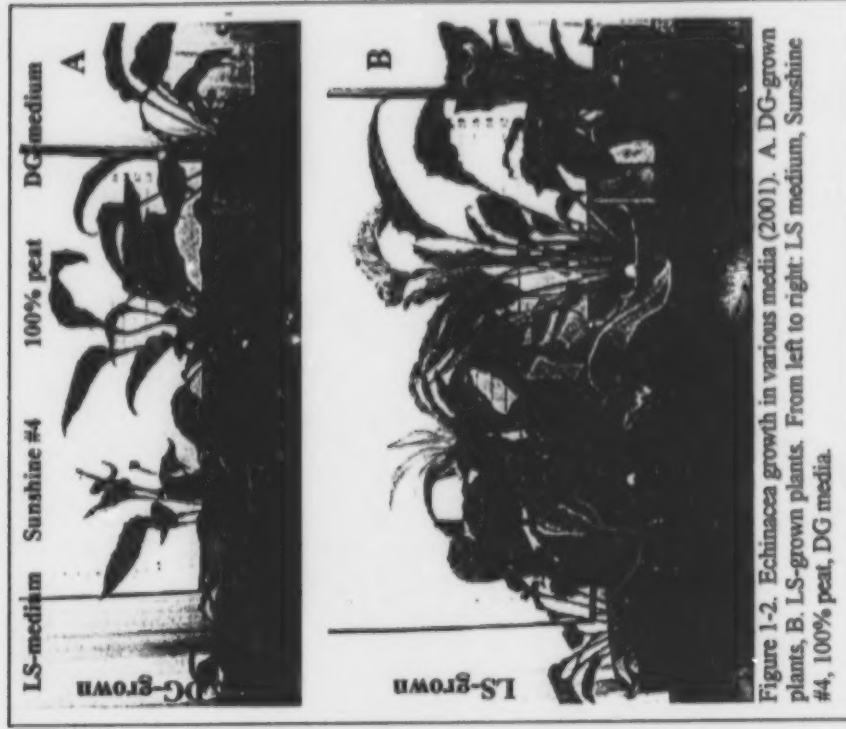
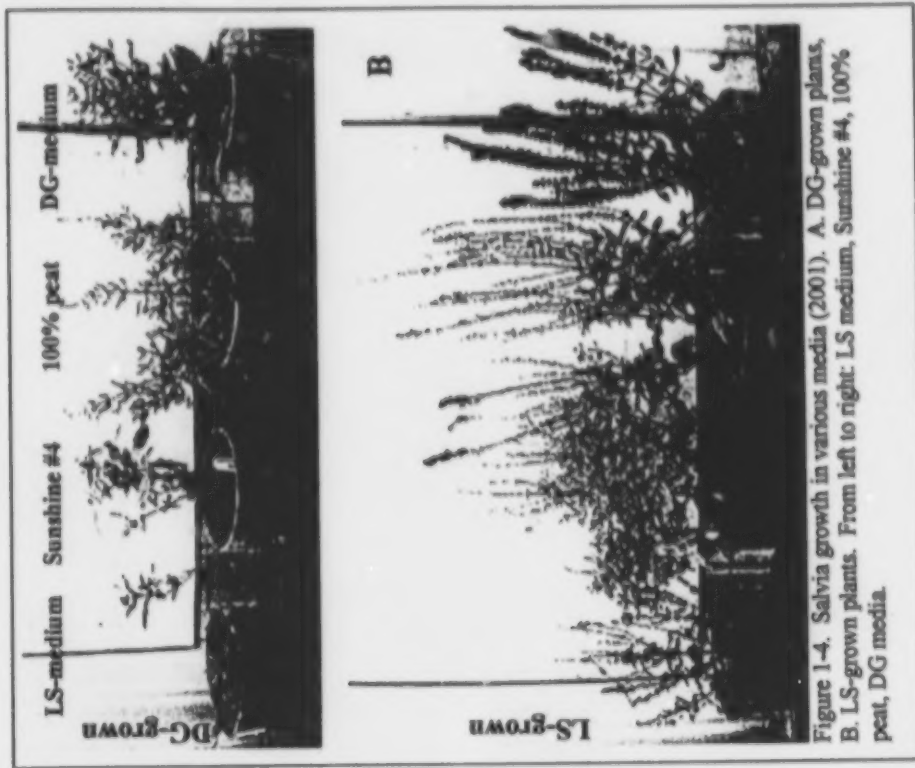
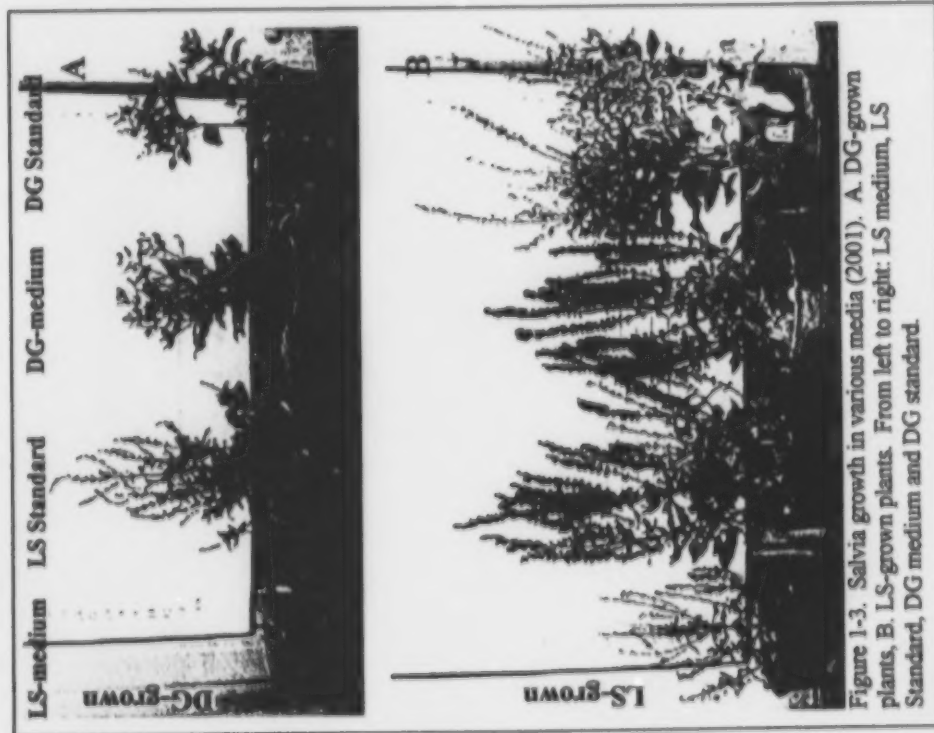


Figure 1-2. Echinacea growth in various media (2001). A. DG-grown plants, B. LS-grown plants. From left to right: LS medium, Sunshine #4, 100% peat, DG media.



Trial #2: Determine optimum container size for herbaceous perennial production (large mature plants)

Container size played a much larger role in plant productivity than expected. Even small changes in container size can result in significant changes in plant growth. Murray (1995) found this to be the case with woody ornamentals. An increase in plant productivity in response to increasing container size makes sense for a number of reasons. Absolute nutrient levels (i.e. amount of fertilizer per container), whether supplied from controlled release fertilizer incorporated in the medium or water-soluble fertilizer in the irrigation water, increase as container size increases. Finally, root zone temperatures fluctuate less as container size increases. The more media that a container can hold, the more water that can be stored in that container. The extra water helps moderate temperature changes that can occur in an unprotected black-walled container. From a production standpoint, the fewer times a plant must be bumped-up to a larger pot the more likely plants will realize their maximum growth potential because there is less transplant shock. Also, less labour is expended per plant, reducing production costs.

Materials & Methods:

1999

Site:

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm

Media:

DG-Standard woody ornamental medium (70% composted bark chips + 30% peat + standard fertilizer amendments)

Container Size:

15 cm standard round container (1.5 litre)

standard 1 gallon nursery container (2.7 litre)

standard 2 gallon nursery container (5.6 litre)

Species:

Nepeta subsessilis (bare-root)

Coreopsis verticillata (bare-root)

Salvia x nemorosa 'May Night' [this species was severely affected by Aster Yellows (*Clorogenus callistephi*) and was removed from the trial]

Plants were potted up on May 5, 1999 at DG and were placed out in the woody ornamental production area. There were five replicates with three plants per replicates for each treatment and species. Plants were arranged in a Completely Randomized Design (CRD) within each species. Plants were harvested on September 29, 1999. Number of main stems (*Nepeta* only) and above ground fresh and dry weights were recorded. Data was tested with ANOVA and LSD (Fisher's protected) was used to separate treatment means whenever $p \leq 0.05$.

2000 & 2001

NOTE: The number of species was reduced in the 2000 trials to accommodate increased replicates as an attempt to reduce experimental variability. Therefore, the species and plant source used in 1999 were not used in subsequent trials.

Site:

LS: Lakeshore Tree Farms, Ltd. - 11th St. container farm

Medium:

LS medium (65% sawdust + 25% peat + 10% sharp Bermuda sand)

[medium was amended with $1.2 \text{ kg N/m}^3 = 2.0 \text{ lb N/yard}^3$ from Osmocote Pro 22-3-8 in 2000. The fertilizer rate in all 2001 trials was reduced to $0.6 \text{ kg N/m}^3 = 1.0 \text{ lb N/yard}^3$ The decision to reduce the rate was based on 2000 fertilizer rate trial results. Each container was amended individually: no bulk mixing]

Container Size:

55 Jumbo (55D) square container (1.35 liter)

15 cm standard round container (1.5 liter)

standard 1 gallon nursery container (2.7 litre)

standard 2 gallon nursery container (5.6 litre)

Species:

Echinacea purpurea 'Bright Star' (seedling)

Salvia nemorosa 'Mai Nacht'* (cutting)

* *Salvia* 'Mai Nacht' (2000 *salvia* cv) was unavailable at time of ordering and a similar cv (*Salvia* 'Blue Queen') was substituted in 2001

Perennials were ordered from Bowman Greenhouses (BC) as 128-plug cell rooted cuttings. Plants were delivered in the week of June 21 2000 and June 1 2001 and transplanted into 2.73 litre nursery containers (Lerio #010). There were 10 replicates of 3 plants/per replicate (4 container size x 10 replicates x 3 plants/replicate = 120 plants) for *Echinacea* and *Salvia*. Treatments were arranged in a Completely Randomized Design (CRD). Survival, plant height, number of stems, fresh weight and dry weight data was recorded in the week of September 1 2000 and September 11 2001. Data was analyzed with ANOVA and treatment means compared with Fisher's protected LSD.

Results & Discussion

1999

Container size had a significant impact on the growth of both *Nepeta* and *Coreopsis*. In general, the larger the container, the higher the dry weight. Specifically, *Nepeta* plant dry weights differed significantly ($p \leq 0.01$) among container size treatments. *Coreopsis* plant dry weight followed a similar trend, but the differences were less dramatic: dry weights from the 15-cm containers were significantly lower ($p \leq 0.05$) than those of the 5.6-liter container whereas dry weights from the 2.73 litre container were equivalent to both of the other container size treatments (Table 2-1).

Nepeta stem numbers were also affected. Both the 15-cm and 2.73 litre containers produced significantly ($p \leq 0.01$) fewer stems than the 6-liter container but were themselves equivalent in terms of stem production (Table 2-1).

There was no surprise that the plants grown in the 6-liter container were larger than those in the smaller containers. What was surprising was that even a small difference in container size had a significant impact on final plant size. This presents a very strong argument to transplant into the

finished size container as soon as possible. Not only does this strategy maximize plant growth but also, by eliminating intervening container sizes, labour is substantially reduced.

2000 & 2001

In 2000, both echinacea and salvia dry weights responded linearly ($p \leq 0.01$) to an increase in container size. That is, as container size increased, so did plant size. In 2001, there was a decline in plant size in the largest (2-gallon) container size, resulting in significant ($p \leq 0.01$) quadratic response to container size for all measured characteristics in echinacea and salvia (Tables 2-2 & 2-3) (Figure 2-1).

The difference between 2000 and 2001 results may be a result of changes in irrigation management, where the largest containers were kept too wet throughout the season to ensure that the majority (i.e. the smaller 1-gallon containers) in this production area were irrigated optimally. The increase in plant size between the smallest container (55 Jumbo) and the 1-gallon container size (all marketable container sizes) was nearly double for both echinacea and salvia in 2001. This argues very strongly that if there is a market for a larger herbaceous perennial (premium size = premium price), the initial propagule, whether dormant bareroot, rooted cutting or seedling, should be potted into its final container size as soon as possible. Gradual bumping-up, as is traditional, is not required.

Summary

Large containers result in large plants. Provided that the grower has a market for a premium sized plant (= premium priced), plugs or bare-root plants should be potted into their final container size. Making room from the larger container in the growing area should be a secondary concern.

Table 2-1. The effect of container size on the growth of *Nepeta* and *Coreopsis*

Container size	<i>Nepeta</i>		<i>Coreopsis</i>
	dw (g)	stems	dw (g)
15-cm rnd (= 1500 liter)	10.6	5.7	16.0
1 gallon (= 2200 mL)	15.2	6.2	20.8
2 gallon (=5560 mL)	29.6	9.1	28.2
Statistical Analysis [†]			
Significance	**	**	*
LSD	2.9	2.5	9.5
CV%	16.0	36.6	59.5

†: * and ** significant at $p \leq 0.05$ and 0.01 , respectively

Table 2-2. The effect of container size on the growth of echinacea

Container size	Volume (mL)	2001			2000		
		stems	crowns	dw (g)	stems	crowns	dw (g)
55 Jumbo (sq)	1350	0.00	2.07	4.89	0.0	1.9	2.3
15 cm (rnd)	1500	0.00	2.53	3.48	0.1	1.9	2.5
1 gallon	2200	0.13	4.10	9.99	0.3	3.9	5.5
2 gallon	5560	0.00	2.07	4.10	0.4	3.4	6.2
Statistical Analysis							
Significance [†]		**	**	**	ns	**	**
Linear Trend		ns	ns	ns	ns	** ($F_{calc} = 12.2$)	** ($F_{calc} = 18.5$)
Quadratic Trend		**	**	**	ns	** ($F_{calc} = 24.9$)	** ($F_{calc} = 8.9$)
LSD		0.10	0.86	2.53	-	1.0	2.4
CV%		8.33	26.1	37.0	65.8	21.7	23.4

† - ns = not significant; ** = significant at $p \leq 0.01$

Table 2-3. The effect of container size on the growth of salvia

Treatment	Volume (mL)	2001		2000	
		stems	dw (g)	stems	dw (g)
55 Jumbo (sq)	1350	2.63	5.75	3.0	4.2
15 cm (rnd)	1500	3.03	8.03	3.0	6.4
1 gal	2200	4.93	11.51	3.9	8.9
2 gal	5560	2.50	8.01	4.3	15.2
Statistical Analysis					
Significance [†]		**	**	ns	**
Linear trend [†]		ns	ns	*	**
Quadratic [†]		**	**	ns	ns
LSD		1.45	2.13	-	4.5
CV%		36.2	21.03	26.2	34.5

[†] - ns = not significant; * and ** = $p \leq 0.05$ and 0.01 , respectively



Figure 2-1. Echinacea (top) and salvia (bottom) growth response in various sized containers. From left to right 55 Jumbo Deep (missing in echinacea), 15 cm round, 1 gallon (2.73 L), 2 gallon (5.73 L)

Trial #3: Determine optimum fertilizer rate for container production of herbaceous perennials

A large cost component of any container operation is fertilizer and of all factors required for good growth, producers have the most control over fertility. Nitrogen rate has the largest effect on plant growth. As with many things, the popular myth is that if some is good, more is better. With fertilizer, this may be true to a point but once that point has been reached, more can be detrimental to growth. At the one extreme, inadequate nitrogen levels will lead to plants with low vigour, low yield and a tendency to be yellow. At the other extreme, too much (excess) nitrogen will lead to reduced plant growth and plants may even die due to salt effects (burning). Between too little and too much there can be a broad range of safe nitrogen rates where an increase in rate translates to an increase in growth rate. There is also the possibility of diminishing returns; that is once a certain growth rate has been achieved, trying to induce higher growth rates with higher fertilizer levels may not result in an equal or corresponding increase in growth rate (i.e. fertilizer use efficiency declines). Overuse of fertilizer may not necessarily result in a decline in growth but it is clearly a waste of resources and a potential source of environmental pollution.

Material & Methods

1999

Site:

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm

Media:

DG-Standard woody ornamental medium (70% composted bark chips + 30% peat)

Fertilizer (HighN 19-5-8) rates:

0.6 kg N/m³ (1.5 lb. N/yard³)

1.2 kg N/m³ (2.0 lb. N/yard³)

1.8 kg N/m³ (2.5 lb. N/yard³)

Species:

Liatris spicata (corm)

Helenium autumnale 'Moerheim Beauty' (bare-root)

Erigeron speciosus 'Azure Fairy' (Etera container) [There was a high level of mortality in this species and was removed from the study]

Media and fertilizer were bulk-mixed just prior to potting up. Plants were potted up in 2.73 litre nursery containers on May 5, 1999 at Dutch Growers Garden Centre Ltd. production farm and were placed out in the woody ornamental production area. There were five replicates with three plants per replicate for each treatment and species. Plants are arranged in a Completely Randomized Design (CRD) within each species. Plants were harvested on September 29, 1999. Where appropriate, number of main stems and above ground fresh and dry weights were recorded. Data was tested with ANOVA and LSD (Fisher's protected) was used to separate means whenever $p \leq 0.05$.

2000 & 2001

Site:

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm

Medium:

LS medium (65% sawdust + 25% peat + 10% sharp Bermuda sand)

Nitrogen rates:

0.6 kg N/m³ (1.5 lb N/yard³)

1.2 kg N/m³ (2.0 lb N/yard³)

1.8 kg N/m³ (2.5 lb N/yard³)

[treatment containers were amended with fertilizer individually: no bulk mixing]

Species:

Echinacea purpurea 'Bright Star'

Salvia nemorosa 'Mai Nacht'* (cutting)

* *Salvia* 'Mai Nacht' (2000 *salvia* cv) was unavailable at time of ordering and a similar cv (*Salvia* 'Blue Queen') was substituted in 2001

Media and fertilizer were mixed just prior to potting up. Perennials were ordered from Bowman Greenhouses (BC) as 128-plug cell rooted cuttings. Plants were delivered in the week of June 21 2000 and June 1 2001 and transplanted into 2.73 litre nursery containers (Lerio #010). There were 10 replicates of 3 plants/per replicate (3 fertilizer levels x 10 replicates x 3 plants/replicate = 90 plants) for *Echinacea* and *Salvia*. Treatments were arranged in a Completely Randomized Design (CRD). Survival, plant height, number of stems, fresh weight and dry weight data was recorded in the week of September 1 2000 and September 11 2001. Data was analyzed with ANOVA and treatment means compared with Fisher's protected LSD.

Results & Discussion

1999

Both liatris and helenium dry weights had a significant ($p \leq 0.01$) linear response to a linear increase in fertilizer rate. However, in both cases, the difference in dry weights between the medium and high fertilizer rate treatments were non-significant (by LSD). The number of stems in both species followed a similar trend to that of dry weight, but mean differences and trends were only significant ($p \leq 0.05$ and 0.01 , respectively) in liatris (Table 3-1).

While the size of plants (as measured by dry weight and number of stems) increased linearly as fertilizer levels increased, the greatest increase in size occurred between the low and medium fertilizer rates (i.e. dry weight increase 270% for liatris and 200% for helenium as fertilizer increases from 0.6 to 1.2 kg N/m³). There was no significant difference between the medium and high fertilizer rates with respect to growth for these two species. This suggests that a reasonable fertilizer rate that produces a reasonable amount of growth is the middle rate (1.2 kg N/m³ = 2 lb N/yard³).

2000 & 2001

In 2000, fertilizer rate had no effect on echinacea stem and crown number but there was a significant ($p \leq 0.01$) negative linear effect on plant dry weight (i.e. dry weight decreased as fertilizer rate increased) (Table 3-2). In salvia, fertilizer rate also had no effect on stem number but there was a significant ($p \leq 0.05$) quadratic effect on plant dry weight (i.e. dry weight was maximal in the 1.2 kg N/m³ treatment) (Table 3-3).

The 2001 results were quite different from 2000 and were more similar to 1999 results. Specifically, echinacea stem number, crown number and dry weight increased linearly ($p \leq 0.01$, 0.05 and 0.01, respectively) in response to increased fertilizer rate (Table 3-2). Salvia stem number did not respond to increased fertilizer rate, but there was a significant ($p \leq 0.01$) linear increase in dry weight (Table 3-3) (Figure 3-1).

The 2000 results suggested that a low to moderate level (0.6 to 1.2 kg N/m³) was optimal for herbaceous perennial production and therefore, the fertilizer levels in all 2001 treatments were reduced from 1.2 to 0.6 kg N/m³. However, the 2001 results would suggest otherwise, that moderate to high fertilizer rates are optimal. There are a number of important differences between the two years that may explain trial results. First, initial plant quality was lower in 2000. Plants were shipped from the grower on the promised date, but were held up in transit for 9 days. Salvia plants arrived with quite a lot of decay and a number of plants did not survive. Echinacea plants were less obviously affected by shipping conditions. These weakened plants may have initially reacted adversely to relatively high fertilizer rates. Secondly, 2001 was a warmer growing season than 2000 and irrigation management was improved at LS. Plants, in peak health at potting-up, would have responded to both conditions and be able to take advantage of increased fertilizer levels. As economics are an important concern, growers must consider whether the increased growth achieved by increasing fertilizer rates will result in a more marketable plant and whether the increased expense can be recovered in a premium priced plant given the highly competitive nature of the industry.

Summary

In two out of the three years, plant growth increased as fertilizer levels increased but in less than a one-to-one relationship (i.e. doubling fertilizer rate did not double plant size). Therefore a low to moderate fertilizer level (0.6 to 1.2 kg N/m³ = 1.5 – 2.0 lb N/yd³) is a good compromise between cost and maximizing plant size.



Figure 3-1 Echinacea (top) and salvia (bottom) growth response to fertilizer rate (2001). From left to right: 0.6 kg N/m³, 1.2 kg N/m³ and 1.8 kg N/m³ (= 1.5 lb N/yd³, 2.0 lb N/yd³ and 2.5 lb N/yd³).

Table 3-1. Liatris and helenium growth with three fertilizer levels grown at Dutch Growers container production farm over the 1999 growing season

Fertilizer Level	Liatris		Helenium	
	stems	dw (g)	stems	dw (g)
0.6 kg N/m ³	0.88	18.42	3.64	12.95
1.2 kg N/m ³	2.38	51.83	4.45	25.82
1.8 kg N/m ³	3.50	51.41	4.75	32.53
Statistical Analysis				
Significance [†]	*	**	ns	**
Linear Trend [†]	**	**	ns	**
Quadratic Trend [†]	ns	*	ns	ns
LSD	1.61	25.99	-	9.12
CV%	47.5	30.2	43.9	34.3

† - ns = not significant; *, ** = significant at $p \leq 0.05$ and 0.01 , respectively

Table 3-2. Effect of fertilizer rate on the growth of Echinacea (Lakeshore)

Media	Fertilizer rate (kg N/m ³)	2001			2000		
		stems	crowns	dw (g)	stems	crowns	dw (g)
Sunshine #4	0.6	0.70	6.13	19.32	2.10	5.60	14.71
Sunshine #4	1.2	1.53	6.40	27.04	1.97	5.17	12.42
Sunshine #4	1.8	2.30	7.50	36.69	2.03	5.00	11.37
Statistical Analysis							
Significance [†]		**	ns	**	ns	ns	**
Linear Trend [†]		**	*	**	ns	ns	**
Quadratic Trend [†]		ns	ns	ns	ns	ns	ns
LSD		1.04	-	7.06	-	-	2.35
CV%		33.5	21.1	20.6	65.8	21.7	23.4

† - ns = not significant; *, ** = significant at $p \leq 0.05$ and 0.01 , respectively

Table 3-3. Effect of fertilizer rate on the growth of Salvia (Lakeshore)

Media	Fertilizer rate (kg N/m ³)	2001		2000	
		stems	dw (g)	stems	dw (g)
Sunshine #4	0.6	8.57	15.60	4.21	9.75
Sunshine #4	1.2	8.60	21.90	4.90	12.02
Sunshine #4	1.8	8.73	27.14	4.07	7.63
Statistical Analysis					
Significance [†]		ns	**	ns	*
Linear Trend [†]		ns	**	ns	ns
Quadratic Trend [†]		ns	ns	ns	*
LSD		-	6.77	-	3.35
CV%		18.8	25.4	26.2	34.5

† - ns = not significant; *, ** = significant at $p \leq 0.05$ and 0.01 , respectively

Trial #4: Evaluate the effect of fertilizer source (manufacturer and formulation) on growth of containerized herbaceous perennial plants

There are a variety of formulations and manufacturers of controlled release fertilizers (CRFs). Each manufacturer's product has a different release system (e.g. chemical weathering or breakdown [e.g. WoodAce and Apex]; encapsulation in one or more different kinds and thickness of porous material [e.g. Osmocote and Nutricote]), each product will be composed of varying amounts and sources of nitrogen, phosphorous and potassium, and the final product may or may not contain micronutrients. Add to that varying longevity and application methods (topdress vs. preincorporate), and growers are presented with a difficult choice of which fertilizer to use. Thankfully, there are a few guidelines.

1. Preincorporated CRF has been shown to produce a more consistent product than topdressed CRF (Hicklenton & McRae, 1989). CRF does of course need to be topdressed on a second year crop, as the alternative (incorporation) would involve extensive root damage and labour.
2. Longevity of the fertilizer product should be matched to the length of growing season. If the longevity is shorter, the plant will be nutrient-starved by the end of the growing season. If the longevity is longer, the plant may be too lush in fall and suffer from storage problems (dieback or winterkill) or encapsulated fertilizer prills may burst overwinter leading to fertilizer toxicity problems (salt damage) in the following spring.
3. If the media that is used for production is soil-less, micronutrients must be added either as a separate amendment or, more conveniently, added as a component of the CRF.

Three CRFs from different manufacturers with similar nutrient composition and longevity were assessed for their suitability under prairie growing conditions and current production management.

Materials & Methods

1999

Sites and irrigation scheme:

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm (pulse)

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm (cyclic)

Media:

DG-Standard woody ornamental medium (70% composted bark chips + 30% peat)

LS-Standard woody ornamental medium (65% sawdust + 25% peat + 10% sharp Bermuda sand)

Fertilizer:

Nutricote 18-6-8 Type 100 (NC)

WoodAce 21-4-10 (WA)

HighN 19-5-8 (HighN)

(fertilizer rate: $1.2 \text{ kg N/m}^3 = 2 \text{ lb N/yd}^3$)

Species:

Heliopsis scabra

Eupatorium purpureum 'Atropurpureum'

Liatris spicata

Fertilizer and media were bulk mixed just prior to potting up. All species were grown with all fertilizers and in both media. *H. scabra* was grown at both sites, *E. purpureum* at Dutch Grower only and *L. spicata* at Lakeshore only. Plants were potted up in 2.73 litre nursery containers on May 6, 1999 at Dutch Growers Garden Centre Ltd. and on May 10, 1999 at Lakeshore Tree Farms Ltd. and were placed out in the respective woody ornamental production areas. There were four replicates with two plants per replicate for each treatment and species. Plants were arranged in a Completely Randomized Design (CRD) within each species. At the end of the season, the number of main stems and above ground fresh and dry weights plants were recorded. Data was tested with ANOVA and LSD (Fisher's protected) was used to separate means whenever $p \leq 0.05$.

2000 & 2001

Site:

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm

Media:

DG-Standard (70% composted bark chips + 30% peat)

[medium was amended with $1.2 \text{ kg N/m}^3 = 2.0 \text{ lb N/yard}^3$ in 2000. The fertilizer rate in all 2001 trials was reduced to $0.6 \text{ kg N/m}^3 = 1.0 \text{ lb N/yard}^3$. The decision to reduce the rate was based on 2000 fertilizer rate trial results. Each container was amended individually: no bulk mixing]

Fertilizer (longevity):

Osmocote Pro 22-3-8 + micronutrients (5 – 6 month)

Nutricote Total 18-6-8 + micronutrients Type 180 (5 – 6 month)

Apex 21-5-6 + micronutrients (3 – 4 month) [Apex was substituted for WoodAce as the supplier no longer dealt with WoodAce products. Also, Apex was similar in nature to WoodAce in that it is not an encapsulated product)

Species:

Echinacea purpurea 'Bright Star'

Salvia nemorosa 'Mai Nacht'* (cutting)

* *Salvia* 'Mai Nacht' (2000 *salvia* cv) was unavailable at time of ordering and a similar cv (*Salvia* 'Blue Queen') was substituted in 2001

Perennials were ordered from Bowman Greenhouses (BC) as 128-plug cell rooted cuttings. Plants were delivered in the week of June 21 2000 and June 1 2001 and transplanted into 2.73 litre nursery containers (Lerio #010). There were 10 replicates of 3 plants/per replicate (3 nitrogen sources x 10 replicates x 3 plants/replicate = 90 plants) for *Echinacea* and *Salvia*. Treatments were arranged in a Completely Randomized Design (CRD). Survival, plant height, number of stems, fresh weight and dry weight data was recorded in the week of September 1 2000 and September 11 2001. Data was analyzed with ANOVA and treatment means compared with Fisher's protected LSD.

Results & Discussion

1999

Heliopsis grown in Nutricote had significantly higher dry weight than in Osmocote and WoodAce ($p \leq 0.01$ and 0.05 , respectively). Eupatorium and liatris did not respond differently to various fertilizer sources (Table 1-2).

2000 & 2001

In 2000, plant dry weight was unaffected by nitrogen source for both echinacea and salvia. However, salvia stem numbers and echinacea stem and crown numbers were significantly ($p \leq 0.05$, 0.01 and 0.01 , respectively) higher when grown in Apex than in Nutricote. Stem and crown number of plants grown in Osmocote and Nutricote treatments were not significantly different (Tables 4-1 and 4-2).

Results in 2001 were similar, with Apex again a superior fertilizer. Echinacea dry weight and crown number and salvia dry weight and stem number was equivalent when grown in either Apex or Osmocote treatments, and both treatments were superior ($p \leq 0.01$) to Nutricote (Tables 4-1 and 4-2) (Figure 4-1).

The 1999 results were quite different from the 2000 & 2001 results where Nutricote performed well in 1999 but poorly in both of the subsequent years. The difference might be species related as none of the 1999 species were used in later years (due to streamlining of treatment design due to a desire to reduce variability). Also, differences in sites between 1999 and 2000 & 2001 may have contributed to treatment differences. What stands out from the 2000 & 2001 results is that Apex, a non-encapsulated product, performed better than the encapsulated products (i.e. Osmocote and Nutricote). The release rate of all three products is controlled by medium temperature; however, the release-rate of the encapsulated products is more temperature dependent than the non-encapsulated one. The consequence of this is that in the earliest part of the growing season, when soil temperature may still be low but air temperature relative high, the release rate of the encapsulated fertilizer may not match plant demand. The non-encapsulated fertilizer is better able to meet plant needs. On the basis of these results growers should consider introducing a non-encapsulated product into their production regime.

Summary

Apex, a non-encapsulated controlled release fertilizer (CRF), outperformed Osmocote and Nutricote, both of which are encapsulated CRF's. This result is likely due to a higher release rate early in the growing season. If cost and ease of use of are equal, growers should consider introducing Apex or other non-encapsulated fertilizers into their fertility regime.

Table 4-1. Effect of fertilizer source on the growth of Echinacea (Dutch Growers)

Fertilizer	2001			2000		
	stems	crowns	dw (g)	stems	crowns	dw (g)
Apex	1.10	4.77	10.62	1.27	6.20	9.31
Nutricote	1.00	3.17	4.42	0.30	4.87	7.86
Osmocote	1.03	4.60	10.94	0.63	5.26	8.75
Statistical Analysis						
Significance [†]	ns	**	**	**	**	ns
LSD	-	0.82	2.52	0.52	1.17	-
CV%	5.4	15.8	23.5	65.2	20.0	21.2

† - ns = not significant; ** = significant at $p \leq 0.01$

Table 4-2. Effect of fertilizer source on the growth of Salvia (Dutch Growers)

Fertilizer	2001		2000	
	stems	dw (g)	stems	dw (g)
Apex	6.27	10.34	5.85	9.24
Nutricote	1.30	3.67	4.19	7.86
Osmocote	4.20	9.42	5.32	7.30
Statistical Analysis				
Significance [†]	**	**	*	ns
LSD	1.31	1.53	1.63	-
CV%	26.9	15.8	29.7	30.4

† - ns = not significant; ** = significant at $p \leq 0.01$

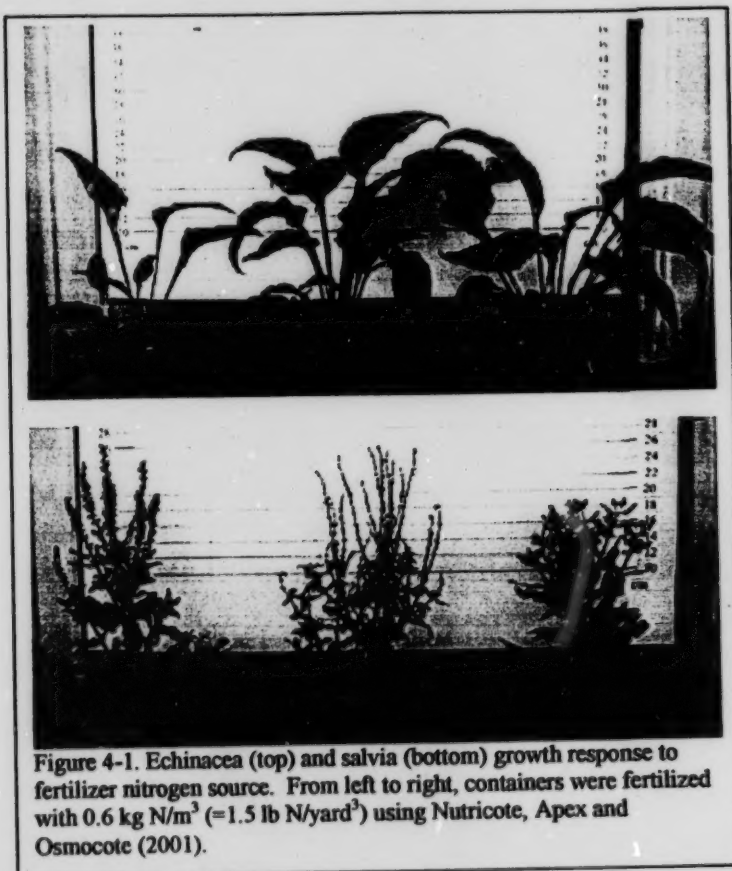


Figure 4-1. Echinacea (top) and salvia (bottom) growth response to fertilizer nitrogen source. From left to right, containers were fertilized with 0.6 kg N/m^3 ($=1.5 \text{ lb N/yard}^3$) using Nutricote, Apex and Osmocote (2001).

Trial #5: To determine optimum medium porosity characteristics suitable for container production of herbaceous perennial plants (2000 – 2001)

Growing medium, whether soil or soil-less, is composed of solid material that is surrounded by space (pores). The pores can hold either water or air, both of which are important to the health and growth of plants. The relative amount of water that a media can hold against gravity at field capacity (saturation) is referred to as water holding capacity (WHC). The remaining pores are air filled at field capacity and this is referred to as aeration porosity (AP).

The ideal field soil has 50% total pore space which is divided equally between WHC and AP. Of course there is no such thing as an ideal or uniform soil and pore space and WHC will vary from field to field and even within fields, making exact irrigation management difficult. A container grower has the advantage over a field grower by being able to create a uniform medium with 'desired' porosity characteristics. According to one grower's guide, a container medium should have $\geq 50\%$ total porosity, 20 – 25% WHC and 20 – 30% AP. Depending on the irrigation scheme, WHC can be adjusted to suit a particular environment without affecting total porosity by adjusting relative amounts of each medium component.

One factor that affects WHC, which is often overlooked, is the phenomenon of a perched water table. This is the level of water in a container that is resistant to gravity at field capacity. This is in addition to the normal WHC: All pores within the perched water table are water filled at field capacity. The perched water table is relatively constant regardless of container size. This means that the shallower the container, the more space is occupied by the perched water table leading to anoxia developing in the lower portion of the container. Therefore, when evaluating the porosity characteristics of a media, it should always be conducted in the container size used for production. If a variety of container sizes are used at a site, the porosity of a medium should be evaluated in each of the container sizes to ensure that it meets all requirements. For example, evaluating a very porous media in only a small container may give a false high WHC value for that medium. If this medium is then used for producing plants in very large containers, the medium may dry out faster than expected leading to drought stress. On the other hand, if a medium tests with a high WHC in a large container and is used to grow plants in small containers, the WHC may be too high in the

smaller container and too little pore space will be devoted to AP at field capacity (again leading to anoxia).

This experiment evaluated plant growth in a number of different media with a variety of porosity characteristics in a single container size (2.73 L = 1 gallon)

Materials & Methods

Site:

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm (pulse)

Media:

0% peat* + 100% bark chips

25% peat + 75% bark chips

75% peat + 25% bark chips

100% peat + 0% bark chips

LS-Standard (65% sawdust + 25% peat + 10% sharp Bermuda sand)

DG-Standard (70% composted bark chips + 30% peat)

Sunshine #4 (peat + perlite commercial greenhouse mixture)

*this is coarse/waste peat, not a milled and compressed horticulture grade

[medium was amended with $1.2 \text{ kg N/m}^3 = 2.0 \text{ lb N/yard}^3$ in 2000. The fertilizer rate in all 2001 trials was reduced to $0.6 \text{ kg N/m}^3 = 1.0 \text{ lb N/yard}^3$. The decision to reduce the rate was based on 2000 fertilizer rate trial results. Each container was amended individually: no bulk mixing]

Species:

Echinacea purpurea 'Bright Star'

* *Salvia* 'Mai Nacht' (2000 salvia cv) was unavailable at time of ordering and a similar cv (*Salvia* 'Blue Queen') was substituted in 2001

Perennials were ordered from Bowman Greenhouses (BC) as 128-plug cell rooted cuttings. Plants were delivered in the week of June 21 2000 and June 1 2001 and transplanted into 2.73 litre nursery containers (Lerio #010). There were 10 replicates of 3 plants/replicate (7 media types x 10 replicates x 3 plants/replicate = 210 plants) for *Echinacea* and *Salvia*. Treatments were

arranged in a Completely Randomized Design (CRD). Survival, plant height, number of stems, fresh weight and dry weight data was recorded in the week of September 1 2000 and September 11 2001. Data was analyzed with ANOVA and treatment means compared with Fisher's protected LSD.

Results & Discussion

In 2000, there was both a significant ($p \leq 0.01$) linear and quadratic response (quadratic dominating) with respect to dry weight to decreasing levels of peat with 100% as the top performer, 25% peat the worst and 0% peat (100% bark) as intermediate. The stem and crown numbers were unaffected. Furthermore 100% peat was significantly ($p \leq 0.01$) better than DG, LS and Sunshine #4 media (Table 5-1). Salvia dry weight response was similar to echinacea. There was a significant ($p \leq 0.01$) linear trend with respect to salvia stem number (i.e. as peat content decreased, so did stem number). Also, stem number in 100% peat treatment was significantly ($p \leq 0.01$) higher than in DG medium (Table 5-2).

The results in 2001 were very similar. Echinacea stem number, crown number and dry weight responded in a significantly ($p \leq 0.05$, 0.01 and 0.01, respectively) linear fashion to decreasing peat levels (i.e. as peat levels decreased, so did stem number, crown number and dry weight). There was no evidence of a quadratic trend in echinacea growth response this year. LS media was the worst performer (see Trial #1: Results and Discussion for possible reasons). Sunshine #4, 100% peat and DG media produced equivalent sized echinacea plants (Table 5-1). There was both a significant ($p \leq 0.01$) linear and quadratic response in terms of salvia stem number and dry weight with the linear trend dominating. The worst treatment in peat treatments was 25% peat and accounted for the quadratic trend. LS medium was the worst treatment (see Trial #1: Results and Discussion for possible reasons). Salvia dry weight was significantly higher in the 100% peat treatment than in DG ($p \leq 0.05$), LS ($p \leq 0.01$) and Sunshine #4 ($p \leq 0.01$) medium. Stem numbers were significantly higher in the 100% peat treatment than in DG and LS media; 100% peat and Sunshine #4 were equivalent (Table 5-2) (Figure 5-1).

The quadratic plant response to decreasing peat levels and increasing bark levels can be attributed directly to the changes in porosity characteristics, in particular water holding capacity (WHC).

WHC is highest in 100% peat (50% WHC) and decreases to a low at 25% peat (38% WHC) and increases slightly at 0% peat (40% WHC) (Table 1-1). These characteristics match the quadratic growth response observed. Aeration porosity seems to be less of a factor and can vary between 15% (as in the case of Sunshine #4 medium) and 30% (100% peat) without sacrificing plant quality (Table 1-1).

It is clear from these results that 100% coarse peat can be used alone to produce high quality herbaceous perennials, replacing the need for the more expensive commercial potting mixtures. In Trial #1 we also saw that DG-Standard medium performed nearly equal or equal to 100% peat. This is somewhat confusing in light of the fact that this media is very close in composition to the 25% peat treatment, which performed poorly compared to 100% peat. WHC is very similar between the two treatments (so is the peat content: 25% vs. 30%), but the aeration porosity (AP) is much higher in the 25% peat treatment than in DG-Standard medium (42% vs 32%) (Table 1-1). It is possible that the higher AP may lead to localized drying out in the media leading to poor water and nutrient distribution and uptake. In any event, these results suggest that high quality herbaceous perennials can be produced using either 100% peat or current standard woody ornamental production media.

Summary

There is a strong relationship between WHC and plant performance: the higher the WHC (up to 50%) the larger the plant. Aeration porosity can vary between 15 and 30% without seemingly affecting growth. 100% coarse peat can be used alone to produce high quality plants replacing the more expensive commercial prepared medium.

Table 5-1. Effect of relative ratios of peat and bark in the growing media on the growth of echinacea

Media		2001			200		
		stems	crowns	dw (g)	stems	crowns	dw (g)
100% peat	(1)	0.20	4.03	10.56	1.21	5.33	14.25
75% peat + 25% bark	(2)	0.03	3.40	7.91	0.30	5.13	6.84
25% peat + 75% bark	(3)	0.00	2.47	4.48	0.27	4.30	6.36
100% bark	(4)	0.00	2.20	3.53	0.88	5.44	9.14
DG medium	(5)	0.03	3.60	9.94	0.63	5.26	8.75
LS medium	(6)	0.03	1.75	1.92	0.88	4.54	10.47
Sunshine #4	(7)	0.28	3.67	10.46	0.68	4.30	11.30
Statistical Analysis							
Significance [†]		**	**	**	**	**	**
Linear Trend (1 - 4)		*	**	**	ns	ns	** (F _{calc} = 26.9)
Quadratic Trend (1 - 4)		ns	ns	ns	**	*	** (F _{calc} = 60.9)
LSD		0.23	0.80	2.12	0.52	1.17	2.43
CV%		18.2	22.2	25.6	65.2	20.0	21.8

† - ns = not significant; ** = significant at $p \leq 0.01$

Table 5-2. Effect of relative ratios of peat and bark in the growing media on the growth of salvia

Media		2001		2000	
		stems	dw (g)	stems	dw (g)
100% peat	(1)	6.17	11.04	7.19	12.23
75% peat + 25% bark	(2)	4.30	7.60	6.79	8.03
25% peat + 75% bark	(3)	1.67	3.37	5.04	8.86
100% bark	(4)	2.75	5.61	3.63	9.74
DG medium	(5)	4.20	9.42	4.69	6.95
LS medium	(6)	1.33	2.65	5.32	7.30
Sunshine #4	(7)	5.58	8.10	6.50	6.43
Statistical Analysis					
Significance [†]		**	**	**	**
Linear Trend (1 - 4)		** (F _{calc} = 87.2)	** (F _{calc} = 113.3)	**	ns
Quadratic Trend (1 - 4)		** (F _{calc} = 21.2)	** (F _{calc} = 40.3)	ns	**
LSD		1.21	1.69	2.17	3.44
CV%		27.3	20.8	29.7	30.4

† - ns = not significant; ** = significant at $p \leq 0.01$



Figure 5-1. Echinacea (top) and salvia (bottom) growth response to a range of relative amounts of peat and composted bark chips. From left to right: 100% peat, 75% peat + 25% bark, DG medium, 25% peat + 75% bark and 100% bark (2001).

Weed Control

Trial #6: Evaluation of chemical and non-chemical weed control in containerized herbaceous perennials

Manual weed control can represent the largest labour cost at a container production farm. In order to reduce costs, growers look to chemical weed control agents. The problem that Canadian growers face is that there are only a limited number of registered pre-emergence herbicides for container production and even fewer that are registered or safe for herbaceous perennial container production. There is no one herbicide that is safe to use on all species and all herbicides represent some risk to the applicator, environment or crop. Non-chemical control methods (other than hand labour) are preferable but in order to be practical, they must be low-cost or reusable and readily available. One grower in Oregon has found that a topdressing of hazelnut shells is an effective weed barrier. Nutshells do not break down readily and will not rob the medium of nutrients. Unfortunately, prairie growers do not have access to hazelnut or other nutshells. Plastic weed barriers used for shrubs and trees are not suitable for use with most herbaceous perennials as new shoots arise from below the ground or at the surface and the plastic weed barrier would block their emergence just as surely as they prevent weed seedling emergence. Of all the agricultural waste products that are available on the prairies, wild rice hulls may be a viable alternative to chemical weed control. This product is purportedly slow to break down and does not absorb water. These characteristics would make it ideal as a weed barrier (Figure 5). Two problems are its low weight and availability (i.e. only source is northern SK) making shipping a relatively high cost component. A small sample was acquired for inclusion with this trial.

Materials & Methods

1999

Site:

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm

Media:

LS-Standard woody ornamental medium (65% sawdust + 25% peat + 10% sharp Bermuda sand + standard fertilizer amendments)

Herbicides & Rates:

Control

Oxadiazon (Ronstar 2G): 0.5 g (10 mg ai)/3 L container = 1/4 teaspoon/3 L container

Napropamide (Devrinol 10G): 0.2 g (20 mg ai)/3 L container = 1/8 teaspoon/3 L

Pendimethalin + Oxyfluorfen (Ornamental Herbicide 2): 0.2 g (6 mg ai)/3 L container = 1/8 teaspoon/3 L

Species:

Heuchera brizoides 'Pluie de Feu' (bare root)

Echinacea purpurea (bare root)

Erigeron speciosus 'Azure Fairy' (Etera container) [There was a high level of mortality in this species and was removed from the study]

Salvia x nemorosa 'May Night' (bare root) [this species was severely affected by Aster Yellows (*Chlorogenus callistephi*); no growth analysis was performed for this species]

Helenium autumnale 'Moerheim Beauty' (bare root)

Eupatorium purpurea 'Atropurpureum' (bare root)

Liatris spicata (corm)

Coreopsis verticillata 'Moonbeam' (bare root)

Veronica longifolia 'Sunny Border Blue' (Etera container) [this species was severely affected by Aster Yellows (*Chlorogenus callistephi*); no growth analysis was performed for this species]

Plants were potted up in 2.76-liter nursery containers on May 10 & 12, 1999 at Lakeshore Tree Farms LTD. and were placed out in the woody ornamental production area. Herbicide was topdressed on May 21, 1999 by measuring the appropriate amount for each treatment container and ensuring that the herbicide was evenly distributed over the container media surface. Plants were harvested on September 16, 1999. The number of main stems, above ground fresh and dry weight, and the number and species of weeds were recorded at the end of the season for the herbicide treatments; the number and kinds of weeds in the hand-weeded treatment were recorded as they are removed throughout the season. There were six replicates with one plant per replicate for each treatment and species. Plants were arranged in a Completely Randomized Design (CRD)

within each species. Data was tested with ANOVA and LSD (Fisher's protected) was used to separate means whenever $p \leq 0.05$.

2000 & 2001

Site:

LS: Lakeshore Tree Farms, Ltd. – 11th St. container farm

DG: Dutch Growers Garden Centre, Ltd. – Beaver Creek production farm

Media:

Standard site media (i.e. at LS, LS-Standard [65% sawdust + 25% peat + 10% sharp Bermuda sand] and at DG, DG-Standard [70% composted bark chips + 30% peat])

[medium was amended with $1.2 \text{ kg N/m}^3 = 2.0 \text{ lb N/yard}^3$ in 2000. The fertilizer rate in all 2001 trials was reduced to $0.6 \text{ kg N/m}^3 = 1.0 \text{ lb N/yard}^3$. The decision to reduce the rate was based on 2000 fertilizer rate trial results. Each container was amended individually: no bulk mixing]

Weed Control:

Control (no weeding)

Oxadiazon (Ronstar 2G): $0.5 \text{ g (10 mg ai)/3 L container} \approx \frac{1}{4} \text{ tsp/3 L container}$

Pendimethalin + Oxyfluorfen (Ornamental Herbicide 2 = OH-II): $0.2 \text{ g (6 mg ai)/3 L container} \approx \frac{1}{8} \text{ tsp/3 L container}$

Napropamide (Devrinol 10G): $0.09 \text{ g (9 mg ai)/3 L container} \approx \frac{1}{8} \text{ tsp/3 L container}$

Wild-rice hull mulch: 2 cm thick layer

Species:

2000:

LS: *Echinacea angustifolia*

Veronica spicata 'Sunny Border Blue'

Campanula carpatica 'Deep Blue Clips'

DG: *Echinacea purpurea* 'Bright Star'

Salvia nemorosa 'Mai Nacht'

2001

LS & DG: *Echinacea purpurea* 'Bright Star'

Veronica spicata 'Sunny Border Blue'

Salvia nemorosa 'Blue Queen'

Campanula carpatica 'Deep Blue Clips'

Perennials were ordered from Bowman Greenhouses (BC) as 128-plug cell rooted cuttings. Plants were delivered in the week of June 21 2000 and June 1 2001 and transplanted into 2.73 litre nursery containers (Lerio #010). There were 10 replicates of 2 plants/replicate (5 weed control methods x 10 replicates x 2 plants/replicate/species = 100 plants/species/site) for all species. Containers were not artificially seeded to weeds but relied on site weed population to provide natural weed population densities in the treatment containers. Treatments were arranged in a Completely Randomized Design (CRD). Survival, plant height, number of stems, fresh weight and dry weight data was collected for the perennial species was recorded in the week of September 1 2000 and September 11 2001; weed species were identified, enumerated and weighed (fresh and dry weight) in each container at that time. Weed data was pooled for all species at each site and containers were rated as either weed free (0) or with weeds (1). This rating system may seem extreme as it ignores the number and size of weeds; however, any weed escapes represent higher management (= labour costs for removal and/or reapplication of herbicide) and lowers crop growth due to competition (light, nutrients and space). Data was tested with ANOVA or Chi-squared (χ^2) and treatment means were compared with Fisher's protected LSD as appropriate.

Results & Discussion

1999

Dry weight:

None of the perennial species (helenium, liatris, heuchera and coreopsis) were negatively affected by the herbicide applications. In fact, liatris had significantly ($p \leq 0.05$) higher dry weight production in the Devrinol treatment than in control (34% increase) (Table 6-1). As noted in the materials and methods, the other three species either succumbed to disease (veronica and salvia) or poor initial planting stock (erigeron).

Weed efficacy: by species

Weed efficacy, while evaluated by species, is not presented because results were very similar for each species with the exception of liatris. In this species, there was no weed growth, even in the control treatment.

Weed efficacy: overall

In the combined weed efficacy analysis, Ronstar and OH-II were equivalent and significantly better than Devrinol and control ($p \leq 0.01$) and both the latter two treatments (Devrinol and control) were equivalent. Only Ronstar provided any significant poplar seedling control, being superior to control ($p \leq 0.01$), Devrinol ($p \leq 0.01$) and OH-II ($p \leq 0.05$). Control, OH-II and Devrinol provided equivalent control with respect to poplar seedlings. All three herbicides were equally effective in controlling grass seedlings and were significantly ($p \leq 0.01$) better than control. OH-II provided the best ($p \leq 0.05$) dandelion control and was equivalent to Ronstar. Ronstar, Devrinol and control were equivalent in dandelion control. Statistically, all treatments provided equal common groundsel control. In order of overall efficacy, Ronstar and OH-II provided the best weed control followed by Devrinol and control (Table 6-2).

OH-II and Ronstar performed equally well and generally better than Devrinol in terms of weed control, and none of the herbicides reduced plant growth. One reason why Devrinol may have failed to perform could be due to the unseasonally wet early summer that we encountered. Devrinol has a half-life of 8 – 12 weeks under 'normal' conditions and may simply have been leached out past the top few centimeters of the media. Other causes of loss of product is photo-reduction and volatilization. These two mechanisms are only important if Devrinol has not been irrigated within 24 hours, which was not the case. The weeds that were in the Devrinol treatment containers were much smaller (i.e. younger; personal observation) than those in the control (although no quantitative measurements were taken aside from number and species), indicating that leaching may have been the cause of late-season weed-growth.

The results from the liatris treatments are interesting. First, the fact that no weeds grew in any of the containers suggests that liatris produces an allelopathic¹ compound that controls weeds. Nowhere, however, is there any report in the literature that liatris has this trait. Furthermore, even if liatris does produce an allelopathic substance, there is no practical or economic way to take advantage of this phenomenon and apply it as a weed control agent for other plants. This remains an interesting observation only. The second incidental observation in the liatris treatments was that plant dry weight was significantly higher in the Devrinol treatment than in all other treatments. Currently, Devrinol's mode of action is not known but there have been at least two studies that have demonstrated Devrinol can affect plant growth positively^{2,3} in strawberries, corn, wheat, radish and soybean. Again, this is an interesting result. Without more detailed work investigating Devrinol's role as a plant growth regulator, Devrinol should be used with the same caution as any other herbicide (i.e. there may be only a fine line between growth stimulation and growth inhibition/death).

2000 & 2001

In both 2000 and 2001, there was a higher weed pressure at DG (based on χ^2 analysis of LS vs DG control treatments). Therefore, DG and LS results will be presented separately.

LS: plant growth

In 2000, plant dry weight of species at LS was significantly affected by treatments. Campanula dry weight was significantly ($p \leq 0.05$) higher in control and Ronstar treatments than in the rice hulls treatment. Echinacea dry weight was significantly ($p \leq 0.01$) higher in the rice hull treatment than in Devrinol and OH-II treatments. Veronica dry weight was significantly ($p \leq 0.01$) higher in the rice hulls treatment than in control and Devrinol treatments (Table 6-3). In 2001, plant dry weight in the rice hulls treatment was highest or equivalent to the highest, in all species. Campanula dry weight was significantly ($p \leq 0.01$) higher in the rice hulls treatment than in Devrinol, OH-II and Ronstar treatments; dry weight was significantly ($p \leq 0.01$) higher in control than in the Devrinol treatment. Echinacea dry weight was significantly ($p \leq 0.01$) higher in the Ronstar treatment than in the Devrinol,

¹ Allelopathy: the release into the environment by an organism of a chemical substance that acts as a germination of growth inhibitor for another organism – The concise Oxford dictionary of Botany (1992). M. Allaby (ed)

² Devlin, R.M., J. Karczmarczyk and I. Zbiec. 1982. Stimulation of plant growth by low concentration of napropamide: Plant Growth Regulation, 1(2): 113-117.

³ Putnam, A.R., and J.F. Hancock. 1982. Influence of napropamide on strawberry growth and fruit yield.

OH-II and control-treatments; dry weight in the rice hulls treatment was equivalent to the Ronstar treatment and significantly ($p \leq 0.01$) higher than in the Devrinol treatment. Salvia dry weight was not affected by herbicide treatments. Veronica dry weight was significantly ($p \leq 0.01$) higher in the rice hulls treatment than in the OH-II and Devrinol treatments; all treatments were significantly ($p \leq 0.01$) better than the Devrinol treatment (Table 6-3).

LS: weed efficacy

2000: Rice hulls provided significantly ($p \leq 0.01$) better weed control than herbicides on average. Specifically, rice hulls controlled weed significantly better than the Ronstar and control treatments. Both OH-II and Ronstar controlled weeds more effectively ($p \leq 0.01$ and 0.05 , respectively) than control. All treatments, except control, controlled weeds significantly ($p \leq 0.01$) better than Devrinol (Table 6-4).

2001: Weed pressure was reduced in 2001 [cp. control percent weed free in 2000 vs 2001] and this fact is reflected in the overall results. Rice hulls, Ronstar and OH-II treatments controlled weeds significantly ($p \leq 0.01$) better than control. The Devrinol treatment was no better than control (Table 6-4)

DG: plant growth

In 2000, echinacea plant growth was greatest in rice hulls treatment. Plant dry weight in both rice hulls and Ronstar treatments were significantly ($p \leq 0.05$) higher than in the Devrinol treatment. Salvia plant dry weight was unaffected by treatments (Table 6-5).

Results in 2001 were more definitive: plant growth in all species was greatest in the rice hulls treatment. In campanula, the rice hulls and Ronstar treatments were equivalent in terms of dry weight; dry weight in the rice hulls treatment was significantly ($p \leq 0.01$) higher than control; and all treatments produced significantly ($p \leq 0.01$) higher dry weight than the Devrinol treatment. Dry weight in echinacea in the rice hulls treatment was equivalent to control and was significantly ($p \leq 0.01$) higher than in the Ronstar, OH-II and Devrinol treatments; and all treatments were significantly ($p \leq 0.01$) better than Devrinol. In contrast to 2000 results, Salvia growth was significantly ($p \leq 0.01$) better in the rice hulls treatment than in any other; all other treatments were equivalent to one another [although the

Devrinol treatment was numerically the highest treatment]. Veronica dry weight was highest [numerically] in the rice hulls treatment and all treatments were significantly ($p \leq 0.01$) heavier than the Devrinol treatment (Table 6-5)

DG: weed efficacy

In 2000, the rice hulls, Ronstar, OH-II and Devrinol treatments controlled weeds significantly ($p \leq 0.01$, 0.01, 0.01 and 0.05, respectively) better than control; the rice hulls and Ronstar treatments were equivalent. Devrinol was the least effective weed control treatment (Table 6-6).

Weed pressure was higher in 2001 [cp. control percent weed free in 2000 vs 2001]. Rice hulls provided significantly ($p \leq 0.01$) higher weed control than all other treatments. Ronstar and OH-II treatments were significantly ($p \leq 0.01$ and 0.05, respectively) better at controlling weeds than control. Control and Devrinol treatments were equivalent (Table 6-6).

When significant differences existed, with only one exception, plant growth in the rice hulls treatment was highest or equivalent to the highest treatment at both locations and in both years. The one exception was campanula growth at LS in 2000 where plant dry weight in the rice hulls treatment was the lowest. Another anomalous result from 2000 was that salvia was unaffected by all treatments. These results may be due to the low initial plant quality. Plants had been shipped from the grower when promised but were in transit for nine days. There was decay and necrosis in both salvia and campanula. Campanula in particular was small and had poor root development and may have reacted adversely to the higher moisture and humidity levels that the rice hulls treatment may have promoted. Unlike the 1999 result, Devrinol had an adverse affect on plant growth. This could be related to its generally poor weed control abilities but the control treatment was either lower than or equivalent in term of weed control to Devrinol and plant dry weights were without exception higher. The only conclusion that can be drawn, therefore, is that Devrinol is detrimental to growth of the herbaceous perennial species used in this study.

Weed control was usually good to excellent in the rice hulls, especially where weed pressure was high and many times outperformed the chemical options tested. Combined with improved growth, rice hulls provide both an economic and effective weed control method. The use of rice hulls as weed control has

been successful that the two co-operators have already incorporated it into their production management (Figure 6-1). If the wild rice processors and nursery growers can devise an inexpensive and efficient means of packaging and transporting wild rice hulls, chemical weed control may become obsolete in the prairies.

Summary

Wild rice hulls, used as a mulch to control weeds, were extremely effective. Since it is a waste product that represents a potential fire hazard up north, this product is free except for shipping. In addition to its weed control abilities, plant growth was enhanced likely due to its effect as a moisture preserving mulch. It is easy to apply, does not interfere with other operations (e.g. irrigation, fertilizer application, etc.), does not require removal before sale, is relatively inexpensive, provides season-long control (possibly multi-season) and provides a chemical-free weed control option to producers.

Table 6-1. Pre-emergence herbicide affects on the growth of 4 container-grown perennials grown at Lakeshore Tree Farms, Ltd. during the 1999 growing season

Herbicide	Helenium		Liatris		Heuchera		Coreopsis	
	stems	dw	stems	dw	crowns	dw	stems	dw
Control (no herbicide)	3.7	12.7	1.5	26.4	9.5	5.1	25.3	6.3
Devrinol	5.3	15.2	2.2	36.4	5.5	4.9	25.4	10.9
OH-II	4.4	10.8	1.7	26.7	5.2	3.6	26.3	10.5
Ronstar	4.2	13.7	1.5	26.0	7.4	7.3	22.3	8.1
Statistical Analysis								
Significance	ns	ns	ns	*	ns	ns	ns	ns
LSD	-	-	-	8.0	-	-	-	-
CV%	46.9	20.0	54.2	23.0	51.1	51.5	66.6	81.4

Table 6-2. Summary of weed control by three pre-emergence herbicides listed by weed species and total weed control in container-grown perennials at Lakeshore Tree Farms, Ltd. during the 1999 growing season.

Herbicide	poplar	grasses	dandelion	groundsel	misc.	total
Control (no herbicide)	4.70	7.93	0.80	1.20	0.00	14.57
Devrinol	4.77	1.47	0.80	2.30	0.21	10.73
OH-II	3.31	0.00	0.00	0.90	0.13	4.31
Ronstar	0.77	0.03	0.13	0.80	0.00	2.10
Statistical Analysis						
Significance	**	**	*	ns	ns	**
LSD	3.20	1.71	0.69	-	-	5.12
CV%	57.6	44.1	132.7	113.9	254.0	39.4

Table 6-3. Pre-emergence herbicide affects on the dry weight (dw) of 4 container-grown perennials grown at Lakeshore Tree Farms production site (2000 - 2001)

Herbicide	Campanula		Echinacea		Salvia	Veronica	
	dw (g)		dw (g)		dw (g)	dw (g)	
	2001	2000	2001	2000	2001	2001	2000
Control (no herbicide)	4.48	5.51	3.44	2.05	6.04	12.86	10.83
Devrinol	2.20	3.78	2.39	1.88	5.54	6.30	10.94
OH-II	3.44	3.75	3.07	1.71	3.89	10.39	13.36
Rice Hulls	5.75	2.86	3.93	3.32	6.05	14.66	15.05
Ronstar	3.59	5.33	4.89	2.35	5.16	12.92	11.49
Statistical Analysis							
Significance [†]	**	*	**	**	ns	**	**
LSD	1.47	1.88	1.43	1.02	-	1.82	3.99
CV%	31.5	69.1	33.4	52.8	52.2	13.3	37.5

[†] - ns = not significant; ** = significant at $p \leq 0.01$

Table 6-4. Effectiveness of 3 chemical and 1 non-chemical weed control methods at Lakeshore Tree Farms production site (2000 – 2001)

Herbicide	Total weed free (%)	
	2001	2000
Control (no herbicide)	63.3	40.0
Devrinol	76.7	36.3
OH-II	93.3	100
Rice Hulls	88.3	87.5
Ronstar	96.7	57.5
Statistical Analysis ^{a,b}	χ^2	signif
Total	32.8	**
Rice vs. control	10.2	**
Rice vs. herbicide	0.0	ns
Rice vs. Ronstar	3.0	ns
Devrinol vs. control	2.5	ns
OH-II vs. control	15.9	**
Ronstar vs. control	20.8	**

a - χ^2 analysis performed using actual numbers rather than percentages

b - significance of χ^2 values are: ns = not significant *, ** = significant at $p \leq 0.05$ and 0.01, respectively

Table 6-5. Pre-emergence herbicide affects on the dry weight (dw) of 4 container-grown perennials grown at Dutch Growers Garden Centre production site (2000 – 2001)

Herbicide	Campanula	Echinacea		Salvia		Veronica
	dw (g)	dw (g)		dw (g)		dw (g)
	2001	2001	2000	2001	2000	2001
Control (no herbicide)	5.05	5.62	11.63	4.89	9.62	11.83
Devrinol	0.94	1.54	7.96	3.99	8.57	5.74
OH-II	4.68	4.14	11.53	5.51	8.82	12.72
Rice Hulls	6.64	6.99	14.50	7.66	8.77	15.00
Ronstar	5.73	4.69	12.75	5.13	8.18	14.43
Statistical Analysis						
Significance [†]	**	**	*	**	ns	**
LSD	1.40	1.59	4.03	1.70	-	3.18
CV%	25.2	28.8	41.8	26.0	44.6	22.1

† - ns = not significant; ** = significant at $p \leq 0.01$

Table 6-6. Effectiveness of 3 chemical and 1 non-chemical weed control methods at Dutch Growers production site (2000 – 2001)

Herbicide	Total weed free (%)	
	2001	2000
Control (no herbicide)	9.4	17.5
Devrinol	0.0	32.5
OH-II	34.4	86.3
Rice Hulls	78.1	73.8
Ronstar	40.6	71.3

Statistical Analysis	χ^2	signif	χ^2	signif
Total	54.6	**	113.7	**
Rice vs. control	30.7	**	51.0	**
Rice vs. herbicide	28.7	**	2.9	ns
Rice vs. Ronstar	22.6	**	0.1	ns
Devrinol vs. control	3.1	ns	4.8	*
OH-II vs. control	5.9	*	75.3	**
Ronstar vs. control	8.3	**	46.8	**

a - χ^2 analysis performed using actual numbers rather than percentages

b - significance of χ^2 values are: ns = not significant *, ** = significant at $p \leq 0.05$ and 0.01, respectively



Figure 6-1. Rice hulls in use at Dutch Growers Garden Centre, Inc. container production farm as a weed control option (2001).

Storage

Trial #7: Evaluation of container size and storage location on herbaceous perennial winter survival

One problem that growers encounter with a multi-year production cycle on the prairies is the need to provide winter protection. Being in containers, otherwise hardy perennials do not have the benefit of a fully protected root zone and most roots will be killed or damaged at relatively high temperatures ($> -10^{\circ}\text{C}$). Further, the smaller the container the higher the likelihood that root zone temperatures may reach damaging levels or be exposed to excessive drought even in a protected environment.

Both Mr. Richard Krahn and Ms. Elsa Belyk, perennial specialists for two of the largest grower/retailers in Saskatchewan (Lakeshore Tree Farms and Dutch Growers Garden Centre, respectively) were consulted regarding overwintering problems that they have encountered in the past. They identified a number of species that were otherwise hardy in a landscape but difficult to overwinter in containers. In an initial assessment (1998, reported in ADF #95000327) of overwintering survival of perennials at both Dutch Growers and Lakeshore, a number of perennials were identified that had an apparent high mortality rate. It was also observed that small container size (i.e. 10-cm diameter and plug sizes) may have contributed in some cases to mortality. Mr. Krahn and Ms. Belyk did not indicate that rodent and moss/algae problems were issues that they had difficulty controlling. In the original proposal, questions regarding fall management practices were raised. These questions will only be pursued if cold, disease and desiccation are ruled out as major factors for winter kill; the perennials identified as difficult to overwinter are strongly responsive to environmental queues and appear to go dormant in the fall under current management practices and in the landscape. We did not pursue the use of abscisic acid (ABA) as a dormancy control agent as Toray (Toray Industries, Inc. Tokyo, Japan) has withdrawn their product from the market and we are no longer able to obtain a commercial supply. While we have a small sample, no more can be obtained, so any research at this time would not be very useful to growers.

We have shown that container size plays a very important role in final plant size, suggesting that important growth advantages (= profitability, better labour management) could be gained if plugs, obtained in late summer (August), are potted up into their final container size, grown on and then exposed to dormancy inducing conditions. The success of this strategy hinges on the ability to provide adequate winter protection.

Materials & Methods

1999/2000

At the end of August 1999, rooted cuttings of *Artemesia schmidtiana* (nana) 'Silver Mound', *Aster novae-angliea* 'Purple Dome', *Lamium maculatum* var. *areum*, *Monarda didyma* 'Petite Delight', *Thymus* 'Golden Creeping' and *Echinacea purpurea* 'Bravado' were received from Skagit Gardens (Mount Vernon, WA). They had been propagated in 128-plug cell trays and shipped by air in a cardboard box. As soon as they arrived, 42 of each species were potted up into their treatment size containers (72-plug cell tray, 10-cm square pots or 3-L nursery container) with Premier Sunshine #4 soil-less media. The potted-up perennials were then placed outside on the lee side (north) of the University

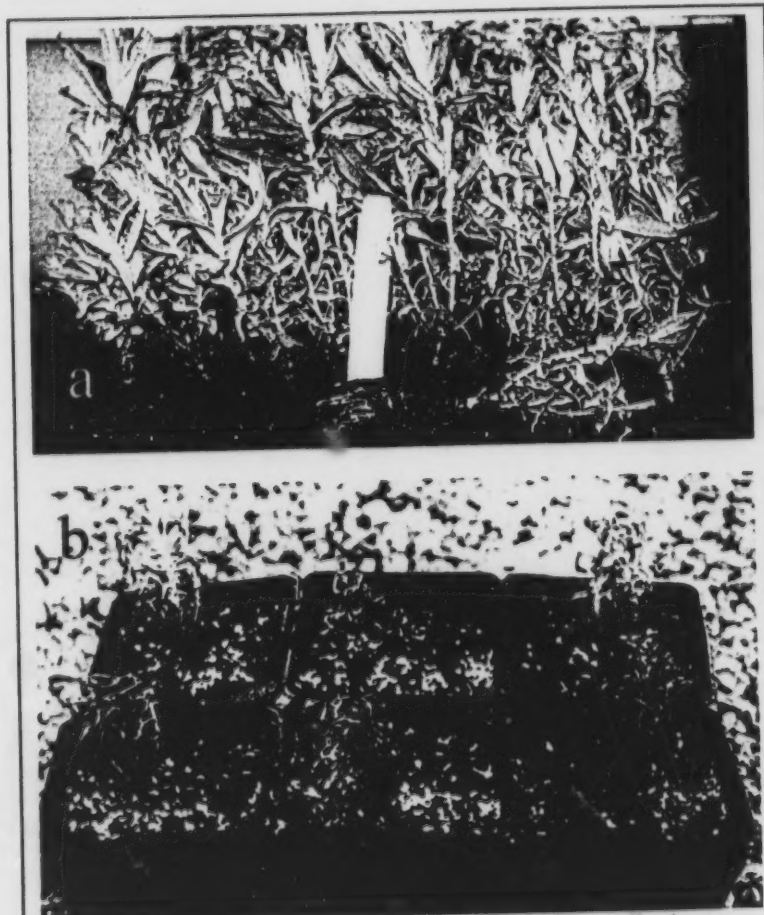


Figure 1. Aster (*Aster novae-angliea* 'Purple Dome') plants; a. healthy appearing plugs upon arrival; b. severely affected by *Rhizoctonia* disease 10 days after transplanting

of Saskatchewan Agriculture Greenhouses and grown on until the end of October, at which time half were transferred to Dutch Growers Garden Centre (Central Rd. retail site) and the other half to Lakeshore Tree Farms (11th Street retail & production site) for storage with each of the co-operators own over-wintering stock. Within days of potting up, the asters began to wither and die. Diagnosis by Dr. Jill Thomson (Dept. of Plant Sciences/U of S Plant Pathologist) identified the problem as *Rhizoctonia* (Figure 7-1). At 10 days post transplant over 80% of the plants were dead and this species was removed from the study.

LS outdoor storage management of herbaceous perennials consists of stacking containers on bare ground to a height of 60 – 90 cm, covered in plastic and then in flax straw to a maximum depth of 30 cm. This area is protected from the wind but is otherwise not sheltered. At DG, perennials are stacked to a height of 60 – 90 cm on asphalt pavement, covered with an insulating tarp and then by an additional reflective (silver) tarp. This area is protected from the wind and is covered overhead by a 3 meter tall shade (lathe) structure.

Temperature monitors were placed with the containers to monitor both air and media storage temperatures to give an indication whether outdoor freeze/thaw conditions affect the plants in storage. Outside air (1.5 m above ground) and soil temperature (5 cm below ground a short distance from the storage pile) was recorded at Lakeshore Tree Farms. Temperature data was also used to help to confirm mortality due to very low temperatures but could not be used in any statistically meaningful way because of the limited number of sensors available.

In spring 2000, plants were removed from storage (March 4 at Dutch Growers and April 19 at Lakeshore as per each site's standard practice). The perennials overwintered at Dutch Growers were grown on in their greenhouse until April 4 at which time they were moved to the University of Saskatchewan greenhouses. They were rated visually on a scale of 0 to 5, 0 being dead and 5 excellent. They were then 'bumped-up' to 3-L nursery containers and grown on for two months. The perennials stored at Lakeshore Tree Farms were treated in the same manner except the initial 1-month growing period took place at the University of Saskatchewan greenhouses. At the end of two months growing-on period all above-ground biomass was harvested. The number of crowns and/or stems, height, spread, fresh weight and dry weight was recorded as appropriate for each

species and data was analyzed with analysis of variance (ANOVA) followed by Fisher's PLSD test or Chi-squared (χ^2), as appropriate.

2000/2001

This trial was a repeat of the 1999/2000 trial except the following species were used: *Thymus praecox pseudolanuginosus* 'Wooly', *Artemisia schmidtiana nana* 'Silver Mound', *Lamium maculatum* 'Aureum', *Gentiana septemfida* var. *lagodechiana*, *Stachys grandiflora* 'Superba' and *Pestemon digitalis* 'Husker Red Strain'. Skagit Gardens (Mt. Vernon, WA) supplied the first three and Bowman Greenhouses (Winfield, BC) supplied the remaining species. The change in species was prompted by availability and by the donation of plant material by Bowman Greenhouses. Plants arrived in good condition on September 15 2000 and were potted up into their treatment containers (plug, 10-cm or 3-L). They were grown on until November 6 2000 in an unheated hoop house at the University of Saskatchewan horticulture field plots, at which time they were transported to Lakeshore Tree Farms or Dutch Growers Garden Centre overwintering facilities. Temperature was recorded over the storage period in each of the container sizes, air temperature in the storage structure, outside air and outside soil. Plants were removed from storage from both locations on April 17, 2001 and placed back into the unheated hoop house for regrowth studies.

Survival and regrowth was determined at the end of the storage period. Site regrowth data was bulked as plants were taken out of storage at the same time and site data had similar error variability. Bulking of data also increased the power of the analysis. The number of crowns and/or stems, height, spread, fresh weight was determined as appropriate for each species. Data was analyzed with Chi-squared (χ^2) or ANOVA followed by Fisher's PLSD test as appropriate.

Results:

Winter Temperatures: 1999/2000

The temperature data recorder at Dutch Growers that was placed in a 3-litre container has been misplaced and therefore no data can be presented for this container size. Data from remaining data loggers have been presented as daily averages over the storage period in graphical form. Maximum, minimum and maximum differences in temperature are derived from the raw data. The following discussion can only make general comments, as there were too few data recorders to analyze the data statistically.

Container size played on a minor role in medium temperature. The smaller the container the closer that medium temperature reacted to changes to air temperature in the storage structure. The medium temperature in 3-L containers was either the same or slightly higher than air temperature (storage) for the majority of the storage period. Medium temperature did not drop below -12°C at either site for any container size during the storage period. Furthermore, medium and air (storage) temperatures did not differ by more than 6.4°C [5.76 and 5.41°C maximum absolute difference for plug and 10 cm containers at Dutch Growers between November 8 and March 4, respectively; 2.51 , 2.4 and 6.31°C for plug, 10 cm and 3-L containers at Lakeshore Tree Farms between November 10 and April 19, respectively] (Figures 7-2 and 7-3).

Outdoor air temperature had the greatest effect on storage conditions, but once there was adequate snow cover, this effect was greatly reduced. As an illustration, compare mid-January and mid-February temperature graphs (Fig. 4 – 6). In mid-January there was sufficient snow-cover to moderate outdoor temperatures effects on storage. By mid-February, there was much less snow cover due to warm temperatures at the end of January/beginning of February and outdoor temperatures had a much greater effect on storage air and medium temperatures (Figures 7-2 and 7-3).

Soil temperature was typically higher than storage temperatures except for plug cells at Lakeshore Tree Farms. This latter observation is likely due to the fact that the plugs were in contact with the ground and were able to take advantage of the greater heat mass of the soil. The temperature in the larger containers was measured near the top of the container (and hence near the crown) and were less protected by the soil heat mass. Had the plug containers been stacked above ground, it is likely that medium and air temperatures would have been less influenced by the soil and more by the outside air temperatures (Figures 7-2 and 7-3).

Winter Temperatures: 2000/2001

The storage datalogger at Lakeshore Tree Farms failed probably due to excess humidity causing the batteries to short out. The regrowth data, therefore, will be the only indication that we had for 2000/2001 season of the effectiveness of the Lakeshore Tree Farm storage system.

The dataloggers recording outside air and soil temperatures at both sites as well as the storage dataloggers at Dutch Growers Garden Centre functioned throughout the storage period between November 2 2000 and April 16 2001.

Outside air temperature did not have a great effect on soil temperature once snow cover was established. Soil temperature did not go below -10°C at any time whereas air temperature was at or below -30°C on a number of occasions. Media temperature (storage), like snow protected soil, did not drop below -10°C during storage and tended to remain in a narrow zone between 0°C and -5°C for the majority of the storage period. This would indicate that the Dutch Growers storage system (insulated tarp covered with silver reflective tarp) protects plant root systems in storage at least as well as snow does in the landscape. Another point that can be drawn from the storage temperature profiles over time is that media temperature is heavily influenced by storage air temperature. This would suggest that the storage coverings should be as air tight as practical to limit exposure to outside air by avoiding air exchange (Figure 7-4).

Mortality:

1999/2000: The ratio of live to dead *Artemesia*, *Echinacea* and *Monarda* did not vary by more than chance, based on container size. There was a significant ($p \leq 0.05$) difference in mortality frequency between 3-L and both of the other container sizes in Dutch Growers stored *Thymus*. In Lakeshore stored *Lamium* there was a significant ($p \leq 0.01$) difference in mortality frequency between 3-L and both of the other container sizes (Tables 7-1a, 7-1b, 7-2a and 7-2b).

2000/2001: The ratio of live to dead *Penstemon*, *Stachys* and *Thymus* did not vary by more than chance, based on container size. *Gentiana* mortality was more affected by disease than by container size (Figure 7-5). The mortality of both Lakeshore and Dutch Growers stored *Artemesia* was affected by container size but to different degrees: at Dutch Growers, the larger the container, the greater the survival but at Lakeshore, plug grown plants had the greatest survival followed by 3-litre and 10-cm grown plants. The mortality of Lakeshore stored *Lamium* was again significantly affected by container size: the greatest mortality occurred in the 10-cm container followed by the 3-litre and plug grown plants.

In 1999/2000 Dutch Growers stored *Lamium* there was a 6-fold difference in mortality frequency between plug and 3-L container grown plants. In other cases, survival was affected but mortality pattern differed between years of sites. Chi-squared (χ^2) is the only appropriate test for this data but due to the low calculated expected mortality numbers overall ($E. \leq 5$), χ^2 may not be able to detect real differences in population ratios. Two possibilities exist: mortality is low and is unaffected by container size or container size affects mortality, but mortality frequency is low enough to be acceptable to the producer.

Visual Quality

In four of the five species overwintered at Dutch Growers Garden Centre, significant differences were evident; only *Thymus* growth was unaffected by container size. For the four species where significant differences existed, perennials stored in 3-L containers were rated significantly ($p \leq 0.01$) higher than those grown in plugs. For *Artemesia*, perennials stored in 10-cm containers were rated ($p \leq 0.01$) higher than those stored in plugs and were equivalent to those in 3-L containers. In the case of *Echinacea*, plant growth was significantly ($p \leq 0.01$) different among all container sizes with plug-grown plants the smallest followed by 10-cm and then by 3-L container grown plants. Plants overwintered at Lakeshore followed a similar pattern but the differences were less dramatic. Lakeshore stored *Echinacea* and *Lamium* were unaffected by storage container size. For the remaining species, plants stored in 3-L containers were significantly ($p \leq 0.01$) larger than those stored in plugs (following regrowth). For *Monarda* plants, those overwintered in 10-cm pots were significantly ($p \leq 0.01$) larger than plug stored plants but equivalent to 3-litre stored plants; all container storage sizes of *Thymus* and *Artemesia* stored plants were significantly ($p \leq 0.01$) different from one another (Table 7-3).

The largest of each species per overwintering container size (1999/2000) were selected and photographed to illustrate differences among treatments. This was to give an indication of the potential differences that could be achieved that may not have been identified through the initial visual rating. [The following discussion describing the photographs cannot be used instead of quantitative analysis and are only provided as a reference.] *Artemesia*, *Echinacea*, *Monarda* and *Thymus* all benefited from overwintering in a large container, which for the most part coincides with the visual rating analysis. The largest *Lamium* was produced in a 10-cm container, which is

in contrast to the visual rating analysis; however, *Lamium* was generally consistently larger in the 3-litre container than in 10-cm container and it was only this one specimen that outgrew the 3-litre size (Figure 7-6) (see also Figure 7-7 for 2000/2001 images).

Regrowth:

1999/2000: Where differences existed, plant dry weight in the 10-cm stored plants was equivalent to the 3-litre stored plants and both were significantly ($p \leq 0.05$) heavier than those stored in plugs. The only exception was *Lamium* where plant dry weight in the 10-cm overwintered plants was significantly ($p \leq 0.05$) higher than plug stored plants and the 3-liter stored plants were intermediate. This latter result may have been due to the generally higher mortality and high variability creating misleading results (Tables 7-4a and 7-4b).

2000/2001: Generally, where differences existed, plants stored in 3-litre containers were significantly larger than those stored in plugs, following the regrowth period. Specifically, *Artemisia* dry weight and stem number, *Gentiana* dry weight, *Penstemon* stem number and *Stachys* dry weight were equivalent in the plug and 10-cm stored plants and the 3-litre stored plants were significantly ($p \leq 0.01$) larger (for all characters above) than both of the smaller sized storage containers; *Gentiana* stem numbers were equivalent in the 10-cm and 3-litre stored plants and both had significantly ($p \leq 0.05$) more stems than the plug stored plants; and *Penstemon* dry weight, *Stachys* leaf number and *Thymus* dry weight differed significantly ($p \leq 0.01$) in all storage container sizes. *Lamium* growth was unaffected by storage container size (Tables 7-5a and 7-5b).

The improvement in growth cannot be attributed to overwintering conditions since mortality was low and temperatures did not reach damaging levels. Increased growth is more likely attributed to improvements in root zone conditions last fall during establishment and this spring during regrowth. A restricted or small rootzone creates an environment prone to water and nutrient deficiencies and also to greater temperature fluctuations. In other words, a larger container (and hence a larger rootzone) is able to hold more water and absolute nutrient levels than a small container and is able to sustain a maximum growth rate. Furthermore, since perennials that are planted in their finished container size do not require intermediate transplanting from small to large containers, loss of potential growth due to transplant shock is eliminated.

Coefficient of Variation (CV%) was high (~ 30%) for *Lamium*, *Thymus*, *Artemesia* and *Monarda*. This may be a reflection that storage conditions played a greater role than was indicated by survival analysis. Surviving plants may have been partially affected by low winter temperatures resulting in non-lethal damage to the growing points and hence high variability in regrowth. CV% was relatively low for *Echinacea* indicating a greater tolerance to low temperature and high relative humidity in storage (Table 7-3).

Lakeshore Tree Farms: In three of the five species overwintered at Lakeshore Tree Farms, significant differences were evident; *Echinacea* and *Lamium* growth was unaffected by container size. For the remaining three species where significant differences existed, perennials overwintered in 3-L containers were rated significantly ($p \leq 0.01$) higher than those overwintered in plugs. For *Artemesia* and *Thymus*, plant growth was significantly ($p \leq 0.01$) different among all container sizes with plug-overwintered plants the smallest followed by 10-cm and then by 3-L container plants. For *Monarda*, plants overwintered in 3-litre and 10-cm containers were equivalent and both were significantly ($p \leq 0.01$) larger than those overwintered in plugs (Table 7-3).

Coefficient of Variation (CV%) was high ($> 30\%$) for a number of species that also had higher overall mortality rates. The surviving plants were likely partially affected by low winter temperatures or by storage disease resulting in non-lethal damage to the growing points and hence high variability in regrowth. CV% was relatively low for *Artemesia* and *Thymus* indicating a greater tolerance to low temperature and high relative humidity in storage. This differed from the results at Dutch Growers where *Echinacea* had a lower CV% and *Thymus* and *Artemesia* had a higher CV% than at Lakeshore. *Echinacea* also had a lower average quality rating at Lakeshore, which argues that it was more damaged by storage conditions than at Dutch Growers. The opposite is true for *Artemesia* and *Thymus*.

The original plant material was grown at one location and clonally propagated and therefore differences in survival and quality can be attributed to storage conditions. The two main differences between the two storage sites were:

- 1) Plant material was stored on bare ground at Lakeshore Tree Farms thus potentially elevating or maintaining high relative humidity levels throughout the storage period

whereas at Dutch Growers Garden Centre, plant material was stored on asphalt which would not contribute greatly to humidity levels

- 2) Snow cover is more important at Lakeshore Tree Farms to provide adequate storage conditions than at Dutch Growers Garden Centre as the insulation value of the Lakeshore Tree Farms storage structure is less than the Dutch Growers Garden Centre's structure. The consequence is that the temperatures within the Lakeshore system is more influenced by ambient temperatures until snow fall than the Dutch Growers system.

A number of conclusions can be drawn from the above results:

- 1) Container size affects plant size: in general, plants grown in large containers are larger than those grown in small containers. This phenomenon is due to the improved root zone environment resulting from improved water and nutrient supplies and a moderation in temperature fluctuations. Furthermore, starting a plant in a finished container size eliminates the labor required to transplant from a smaller to a larger container, reduces the chance that plants will become rootbound and reduces the loss of growth potential due to transplant shock.
- 2) Container size does not seem to affect mortality provided that storage conditions are suitable (i.e. are unlikely to result in lethal or sub-lethal damage).
- 3) Plug-grown perennials acquired in the early fall may be planted in their final container size to maximize growth potential. Some species or individual specimens may be large enough for spring sales. Furthermore, planting in the fall relieves labour pressure during the typically busy spring period and growers are able to take advantage of lower plant costs available in the fall. Fall planting presupposes that growers have adequate storage facilities.
- 4) Perennials should not be watered immediately before placing in storage to ensure that excess moisture is not a negative factor in survival. Rather, if grown outside, they should be watered no later than 1 - 2 days before placing in storage to reduce disease development (personal observations).

Optimum storage conditions do differ among species; however provided that medium temperature is maintained between -1° and -6° C and air (storage) temperature above -10° C, most hardy species should tolerate winter storage with minimal winter loss.

Summary

Storage container size does not greatly affect survival, provided storage temperatures are maintained within a safe zone (-7 – 0°C). Storage container size does affect final plant size, mainly due to increased resources during fall establishment and spring regrowth. Plug grown plants can safely be acquired in the early fall, potted into their final container size and allowed to establish in an unheated greenhouse before placement into the overwintering storage facility. Purchasing plugs in the fall takes advantage of low fall prices and relieves some of the labour pressure in the busy spring. In the case where species are susceptible to storage diseases, a prophylactic fungicide application may be beneficial.

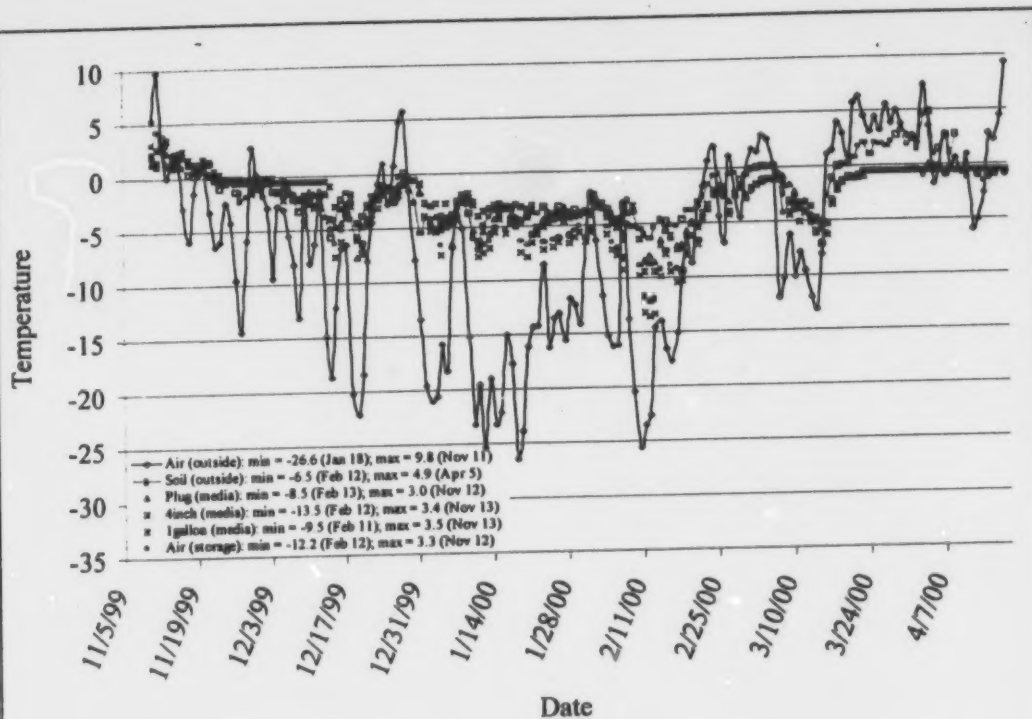


Figure 7-2. DG Storage Temperature (1999/2000)

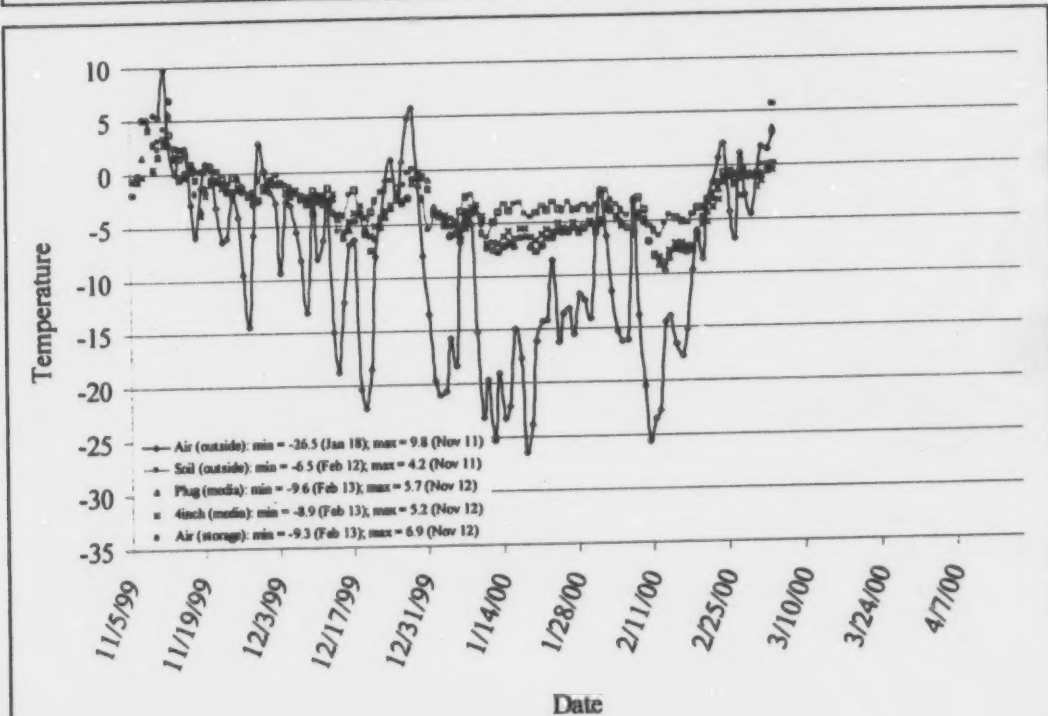


Figure 7-3. LK Storage Temperature (1999/2000)

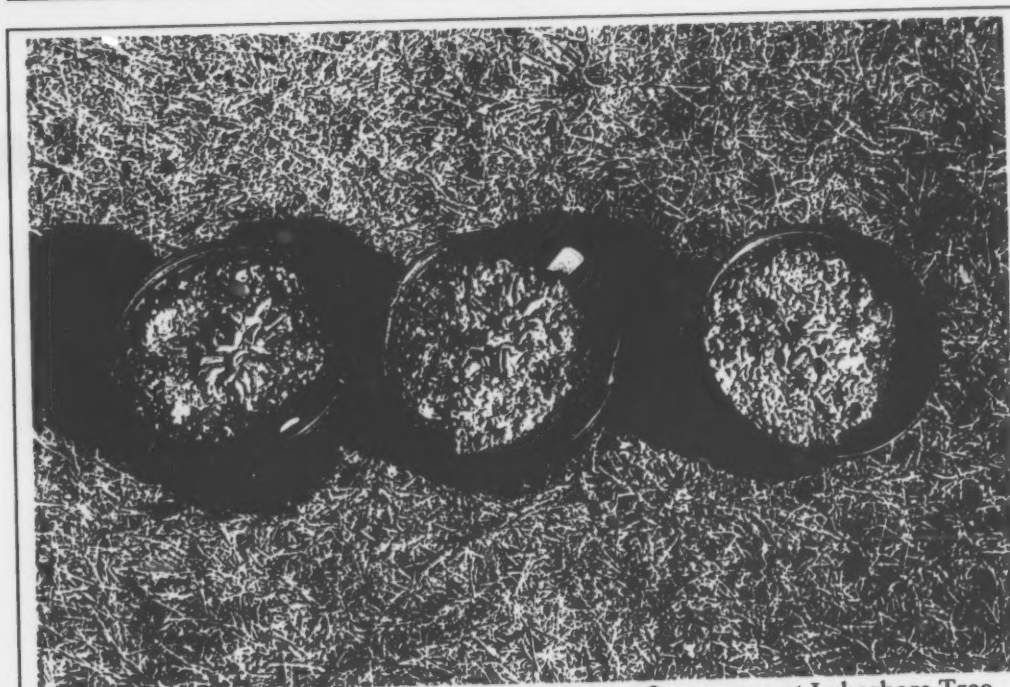
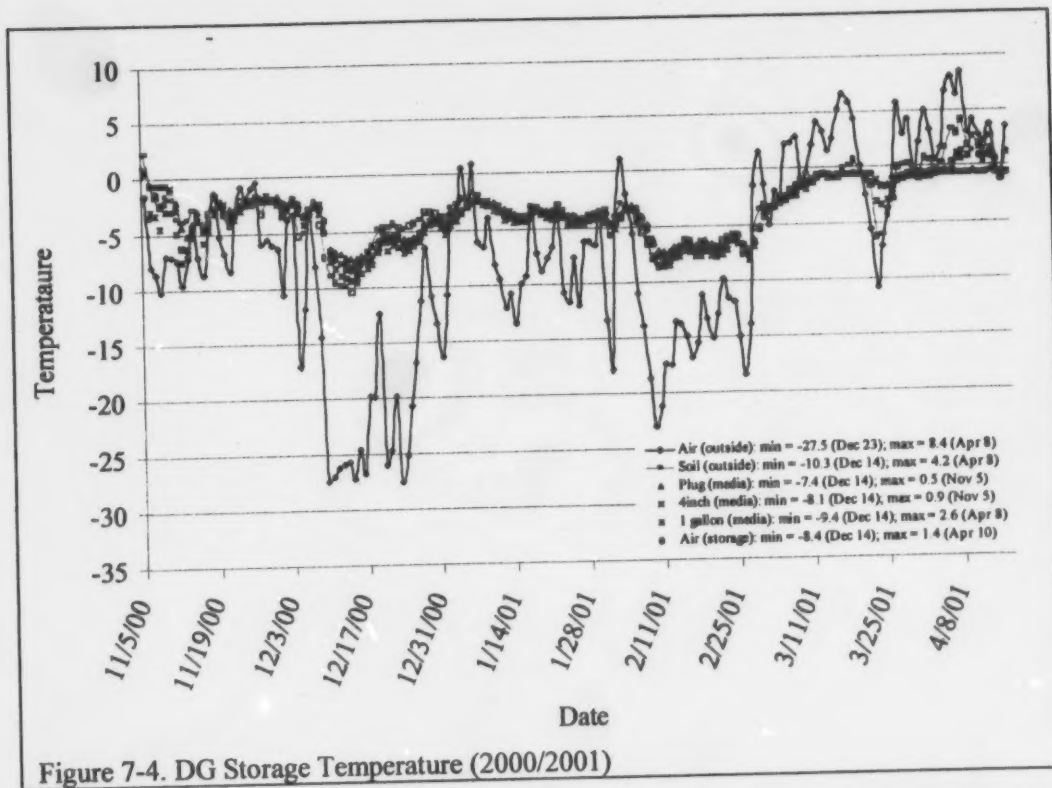


Figure 7-5. *Gentiana septemfida* var. *lagodechiana* after storage at Lakeshore Tree Farms (April 17 2001). The plant on the right was most affected by storage mold and the one on the left, the least affected.

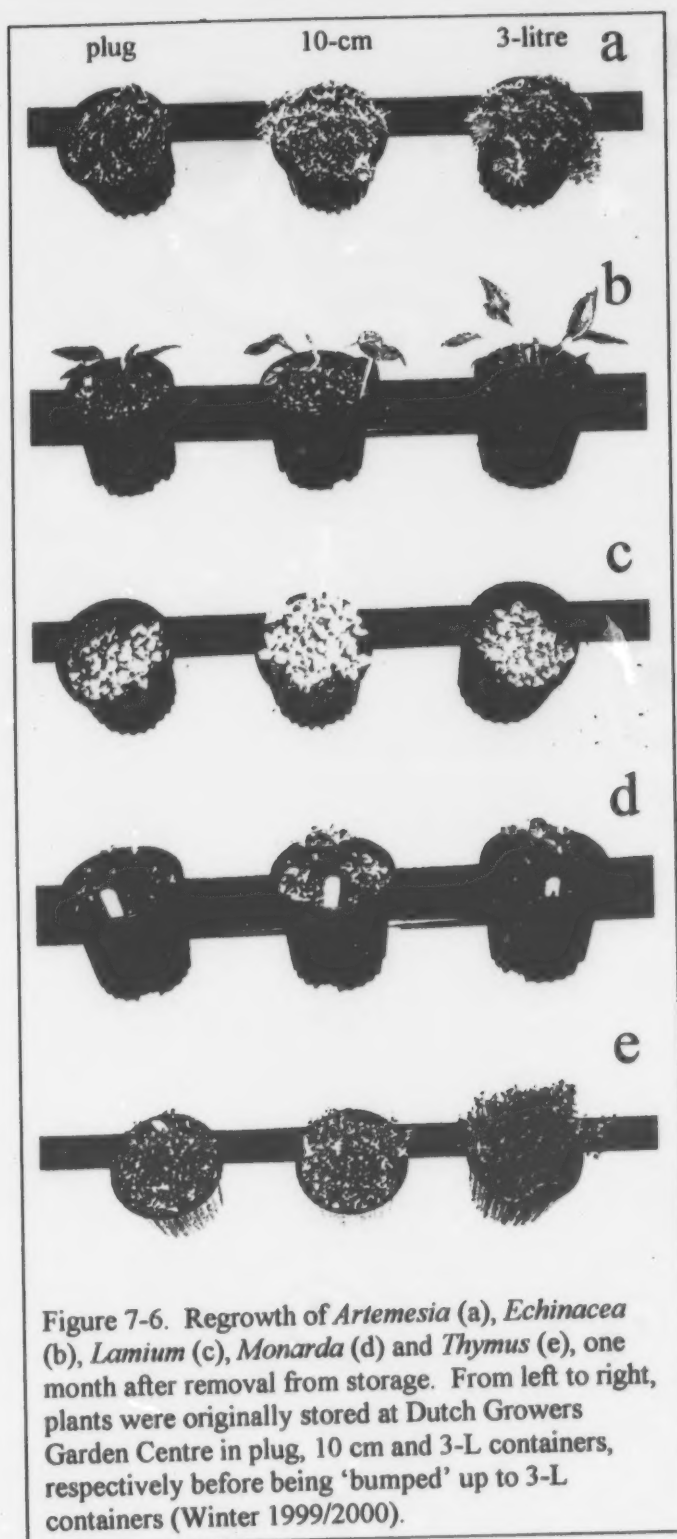




Figure 7-7. Regrowth of *Artemisia* (a), *Stachys* (b), *Gentiana* (c), *Lamium* (d) *Penstemon* (e) and *Thymus* (f), one month after removal from storage. From left to right, plants were originally stored in 2.7-L, 10-cm and plug containers, respectively before being 'bumped' up to 3-L containers (Winter 2000/2001).

Table 7-1a. Mortality (%) of perennials overwintered at Dutch Growers Garden Centre, Ltd.
(Central Ave., Saskatoon)

(Central Ave., Saskatoon)												
	<i>Artemesia</i>				<i>Lamium</i>				<i>Thymus</i>			
Container Size	1999/2000		2000/2001		1999/2000		2000/2001		1999/2000		2000/2001	
Plug	20.0		80.0		6.7		10.5		0		5.6	
10-cm (square)	0		70.0		19.0		5.0		0		0	
3-litre (round)	19.0		31.6		35.3		15.0		14.3		20.8	
Statistical Analysis [†]	χ^2	signif.	χ^2	signif.	χ^2	signif.	χ^2	signif.	χ^2	signif.	χ^2	signif.
	4.71	ns	10.6	**	4.03	ns	1.1	ns	6.15	*	5.90	ns

† - ns = not significant; * and ** significant at $p \leq 0.05$ and 0.01 , respectively

Table 7-1b. Mortality (%) of perennials overwintered at Dutch Growers Garden Centre, Ltd.
(Central Ave., Saskatoon)

Container Size	Echinacea		Monarda		Gentiana		Penstemon		Stachys	
	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001
Plug	0	19.0	19.0	28.6	0	0	0	16.7	0	0
10-cm (square)	9.5	14.3	14.3	15.0	0	0	0	5.0	0	0
3-litre (round)	0	19.0	19.0	10.0	0	0	0	0.0	0	0
Statistical Analysis [†]	χ^2 4.13	signif. ns	χ^2 0.22	signif. ns	χ^2 2.58	signif. ns	χ^2 n/a	signif. ns	χ^2 4.00	signif. ns

† - ns = not significant; n/a = not applicable

Table 7-2a. Mortality (%) of perennials overwintered at Lakeshore Tree Farms (11th St., Saskatoon)

Container Size	Artemesia		Lamium		Thymus	
	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001
Plug	5.3	8.5	0	15.0	0	4.8
10-cm (square)	0	52.4	40.0	70.0	0	4.8
3-litre (round)	5.0	35.0	56.3	35.0	5.6	20.0
Statistical Analysis [†]	χ^2	signif.	χ^2	signif.	χ^2	signif.
	1.12	ns	10.5	**	7.83	*
					12.9	**
					2.15	ns
					3.60	ns

† - ns = not significant; * and ** significant at $p \leq 0.05$ and 0.01 , respectively

Table 7-2b. Mortality (%) of overwintered perennials at Lakeshore Tree Farms (11th St., Saskatoon)

Container Size	Echinacea		Monarda		Gentiana		Penstemon		Stachys	
	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001	1999/2000	2000/2001
Plug	28.6	38.1	38.1	23.8	0	0	0	15	0	0
10-cm (square)	19.0	45.0	45.0	20.0	0	0	0	10	0	0
3-litre (round)	28.6	33.3	33.3	0	0	0	0	0	0	0
Statistical Analysis [†]	χ^2 0.77	signif. ns	χ^2 0.59	signif. ns	χ^2 5.27	signif. ns	χ^2 n/a	signif. ns	χ^2 3.05	signif. ns

† - ns = not significant; n/a = not applicable

Table 7-3. Visual quality rating of surviving perennials overwintered at Dutch Growers Garden Centre (DG, Central Ave., Saskatoon) and Lakeshore Tree Farms (LS, 11th St. Saskatoon) following 1 month of regrowth [2000]

	Visual Quality Rating (1 – poor, 5 – excellent) [†]									
	<i>Artemesia</i>		<i>Echinacea</i>		<i>Lamium</i>		<i>Monarda</i>		<i>Thymus</i>	
Container size	DG	LS	DG	LS	DG	LS	DG	LS	DG	LS
plug	2.38a	2.00a	2.94a	1.86a	2.36a	1.67a	2.29a	1.15a	3.24a	3.00a
10-cm (sq)	3.38b	3.57b	3.84b	2.53a	2.94a	1.33a	2.50a	2.09b	2.95a	3.65b
3-L (rnd)	3.82b	4.53c	4.71c	2.40a	4.00b	1.71a	4.35b	2.36b	3.24a	4.29c
Statistical Analysis										
CV%	31.2	15.8	13.9	35.1	29.1	45.3	29.0	40.3	32.4	19.5

[†] ratings followed by a different letter differ significantly ($p \leq 0.01$) by Fisher's PLSD

Table 7-4a. Evaluation of *Artemesia*, *Echinacea* and *Lamium* overwintered at Dutch Growers Garden Centre (Central Ave., Saskatoon) following 3 months of regrowth [2000]

Container size	<i>Artemesia</i>			<i>Echinacea</i>		<i>Lamium</i>	
	dw (g) [†]	stems [†]	stem length (cm) [†]	dw (g) [†]	crowns [†]	dw (g) [†]	cover (%) [†]
Plug	11.72a	11.94a	12.73a	3.44a	2.29a	0.95a	53.71a
10-cm (sq)	20.62b	15.71a	15.14b	5.65b	3.26b	2.66b	88.44b
3-L (rnd)	18.20b	14.82a	15.81b	6.46b	3.95b	1.36a	62.73ab
Statistical Analysis							
CV%	35.4	44.4	17.9	62.5	44.5	82.0	52.2

[†] ratings followed by a different letter differ significantly ($p \leq 0.05$) by Fisher's PLSD

Table 7-4b. Evaluation of *Monarda* and *Thymus* overwintered at Dutch Growers Garden Centre (Central Ave., Saskatoon) following 3 months of regrowth [2000]

Container size	<i>Monarda</i>			<i>Thymus</i>		
	dw (g) [†]	stems [†]	stem length (cm) [†]	dw (g) [†]	stem length (cm) [†]	cover (%) [†]
Plug	6.371a	3.0a	13.50a	4.85a	15.49a	105.3a
10-cm (sq)	7.629a	4.2a	15.76ab	7.95a	19.52b	132.1a
3-L (rnd)	7.631a	3.9a	16.60b	8.98a	21.63b	135.6a
Statistical Analysis						
CV%	43.9	47.3	21.96	65.3	22.8	39.1

[†] ratings followed by a different letter differ significantly ($p \leq 0.05$) by Fisher's PLSD

Table 7-5a. Evaluation of *Artemesia*, *Gentiana* and *Lamium* following 3 months of regrowth [2001]

Container size	<i>Artemesia</i>		<i>Gentiana</i>		<i>Lamium</i>	
	dw (g) [†]	stems [†]	dw (g) [†]	stems ^x	dw (g) [†]	cover (%) [†]
Plug	12.7a	13.0a	2.4a	27.1a	1.8a	74.1a
10-cm (sq)	19.0a	14.3a	7.2a	38.1b	1.7a	76.9a
3-L (rnd)	29.5b	24.3b	8.0b	33.7b	1.7a	71.7a
Statistical Analysis						
CV%	27.9	35.0	20.1	26.7	49.0	32.7

[†] ratings followed by a different letter differ significantly ($p \leq 0.01$) by Fisher's PLSD

^x ratings followed by a different letter differ significantly ($p \leq 0.05$) by Fisher's PLSD

Table 7-5b. Evaluation of *Penstemon*, *Stachys* and *Thymus* following 3 months of regrowth [2001]

Container size	<i>Penstemon</i>		<i>Stachys</i>		<i>Thymus</i>
	dw (g) [†]	stems [†]	dw (g) [†]	leaves [†]	dw (g) [†]
Plug	9.3a	1.6a	4.6a	28.8a	5.4a
10-cm (sq)	14.6b	2.5a	5.1a	37.2b	12.1b
3-L (rnd)	30.4c	5.4b	10.4b	52.5c	18.3c
Statistical Analysis					
CV%	32.9	46.2	34.9	31.4	26.3

[†] ratings followed by a different letter differ significantly ($p \leq 0.01$) by Fisher's PLSD

Fertility Assessment

Trial #8: Media fertility assessment

There are a number of factors that govern the level of controlled release fertilizer in a container at any given time: how homogenous the media was initially, the average media temperature, the theoretical (labeled) fertilizer longevity and, to a lesser extent, the irrigation scheme. Growers currently have no way of easily assessing media fertility. At the very least, knowing when the fertilizer reserves are depleted would be useful information, allowing growers to make correct fertilizer decisions later in the season. For example, if the plants are chlorotic in early August, is it because the fertilizer levels are zero, is there a root-related problem or disease, is the irrigation frequency too high, or was the fertilizer level too low initially? Each one of these possibilities requires a different solution. Periodic fertility assessment should eliminate the guesswork.

Objective

To develop a fertility assessment protocol for soil-less nursery/perennial media that growers can incorporate into their management scheme.

Materials & Methods

Site:

Dutch Growers Garden Centre Ltd. (Beaver Creek Farm)

Media:

Standard Dutch Growers woody ornamental media (bark + peat)

Treatments:

0 kg N (HighN 19-5-8)/m³

0.6 kg N (HighN 19-5-8)/m³ (= 1.5 lb N/yd³)

1.2 kg N (HighN 19-5-8)/m³ (= 2.0 lb N/yd³)

1.8 kg N (HighN 19-5-8)/m³ (= 2.5 lb N/yd³)

1.2 kg N (HighN 19-5-8)/m³ (= 1.5 lb N/yd³) + plastic weed barrier[†]

1.2 kg N (Prairie Blend 22-3-8)/m³ (= 1.5 lb N/yd³)

Standard Dutch Growers fertilizer amendments

*The weed-barrier is dish shaped, with a raised lip to fit around the top of the container, and has a slot running from the edge to the centre. The slot is designed to fit around plants with one or few central main stems making it ideal for use with woody ornamentals (trees and shrubs).

Containers (2.73-L nursery containers) were filled on May 6, 1999 and placed out in the container growing area.

Evaluation, Design and Analysis:

Five containers from each treatment were harvested during the first week of every month starting in May and continued to October. Leachate samples were collected two hours after thorough watering by pouring and collecting 500 mL distilled water from each container. Media was then dried and ground. Ground-media leachate was collected after subsamples were mixed with distilled water, followed by vacuum filtration. The nitrate (NO_3^-), potassium (K^+), electrical conductivity (EC) and pH levels of leachate samples were measured.

There were five replicates with one container per replicate per treatment. Containers were arranged in a Completely Randomized Design (CRD). Data was tested with ANOVA and LSD (Fisher's protected) was used for mean separation whenever $p \leq 0.05$. Contrast analysis was performed to determine 1) if linear or quadratic relationships existed, and 2) if differences existed between specific treatment means. Finally, correlation analysis was performed to determine how well EC, nitrate and potassium were related.

Results

Whole (non-ground) media leachate analysis

pH:

There was a significant linear increase in pH over the growing season for all treatments (no fertilizer, 0.6 kg N/meter³, standard, barrier and prairie formulation [$p \leq 0.01$]; 1.2 kg N/meter³ [$p \leq 0.05$]) except for 1.8 kg/meter³). The 1.8 kg N/meter³ treatment resulted in anomalous low pH value in July; when the July values were removed from the analysis, the resulting trend line was nearly flat. In May, there was a linear ($p \leq 0.05$) increase in pH in response to an increase in fertilizer level. There was no significant response in June. For the remainder of the year (July –

October), there was a significant linear decrease (July – September: $p \leq 0.01$; October: ≤ 0.05) in pH in response to an increase in fertilizer rate. pH levels in the plastic weed-barrier were significantly ($p \leq 0.05$) higher than in the equivalent fertilizer level treatment without the weed barrier in June; differences were not significant for any other month. Differences in pH levels between 1.2 kg N/meter³ HighN and 1.2 kg N/meter³ Prairie fertilizer treatments were only significant in May (Prairie < HighN: $p \leq 0.01$) and June (Prairie > HighN: $p \leq 0.05$) (Table 8-1, Figure 8-1).

Electrical Conductivity (EC):

EC levels were high in May. There was a linear ($p \leq 0.01$) increase in EC levels as fertilizer level increased for all months except August. EC levels were significantly higher in the plastic weed-barrier treatment than in the 1.2 kg N/m³ treatment in June ($p \leq 0.01$), July ($p \leq 0.05$), August ($p \leq 0.01$), September ($p \leq 0.01$) and October ($p \leq 0.01$) (Table 8-2, Figure 8-2).

Nitrate (NO₃⁻):

There was a linear increase in NO₃⁻ levels with increasing fertilizer levels for the whole growing season ($p \leq 0.05$ for August, $p \leq 0.01$ otherwise). Nitrate levels were higher in the weed-barrier treatment than in the 1.2 kg N/m³ treatment without weed-barrier in June ($p \leq 0.05$) and August through to October ($p \leq 0.01$). Nitrate levels were higher in the Prairie fertilizer treatment than in the HighN treatment in May ($p \leq 0.01$) and September ($p \leq 0.05$) (Table 8-3, Figure 8-3).

Potassium (K⁺):

There was a linear increase in K⁺ levels as fertilizer levels increased for May ($p \leq 0.010$), June ($p \leq 0.05$), September ($p \leq 0.05$) and October ($p \leq 0.01$). Potassium levels were higher in the weed-barrier treatment than in the 1.2 kg N/m³ treatment without weed-barrier in August ($p \leq 0.01$) and October ($p \leq 0.05$). Potassium levels were lower in the Prairie fertilizer treatment than in the HighN fertilizer treatment in May ($p \leq 0.01$) (Table 8-4, Figure 8-4).

Ground-up media leachate analysis

pH:

There was a linear increase in pH over the growing season in the standard fertilizer treatment ($p \leq 0.01$) and a linear decrease in pH over the growing season in the 0 kg N/m³ ($p \leq 0.05$) and weed-barrier ($p \leq 0.05$) treatments. There was a linear decrease in pH levels as fertilizer levels increased in May, June, September and October ($p \leq 0.01$). In July there was a quadratic ($p \leq 0.01$) response to increasing fertilizer rates with respect to pH levels. pH levels in the weed-barrier treatment were significantly lower than the 1.2 kg N/m³ treatment in September ($p \leq 0.05$) and October ($p \leq 0.01$). pH levels were higher in the Prairie fertilizer treatment than in the HighN fertilizer treatment in June ($p \leq 0.05$) (Table 8-5, Figure 8-5).

Electrical Conductivity (EC):

There was a linear increase in EC levels in the no-fertilizer treatment ($p \leq 0.05$) and a linear decrease in the 0.6 kg N/m³ ($p \leq 0.01$), 1.8 kg N/m³ ($p \leq 0.05$) and standard ($p \leq 0.01$) fertilizer treatments over the growing season. There was a linear ($p \leq 0.01$) increase in EC levels in response to increasing fertilizer levels for the entire growing season (May – October). There were no significant differences in EC levels between the weed-barrier and 1.2 kg N/m³ without weed-barrier treatments during the growing season. EC levels were lower in the prairie fertilizer treatment than in the HighN fertilizer treatment in May ($p \leq 0.01$), July ($p \leq 0.05$), August ($p \leq 0.05$) and October ($p \leq 0.01$) (Table 8-6, Figure 8-6).

Nitrate (NO₃⁻):

There was an overall linear decrease in NO₃⁻ levels for the no fertilizer, 0.6 kg N/m³, 1.2 kg N/m³, 1.8 kg N/m³ and standard fertilizer treatments ($p \leq 0.01$) over the growing season. There was a linear ($p \leq 0.01$) increase in nitrate levels as fertilizer levels increased from May to October. Nitrate levels were higher ($p \leq 0.05$) in the weed-barrier treatment than in the 1.2 kg N/m³ without weed-barrier treatment in August and October. Nitrate levels were lower in the Prairie fertilizer treatment than in the 1.2 kg N/m³ treatment in May ($p \leq 0.01$), June ($p \leq 0.05$) and September ($p \leq 0.05$) (Table 8-7, Figure 8-7).

Potassium (K⁺):

There was a general linear decrease in potassium levels in the no fertilizer ($p \leq 0.01$), 0.6 kg N/m³ ($p \leq 0.01$), 1.2 kg N/m³ ($p \leq 0.05$) and standard fertilizer treatments over the growing season. There was a linear ($p \leq 0.01$) increase in K⁺ levels as fertilizer level increased for the whole season. There was no difference in K⁺ levels between the weed-barrier and the 1.2 kg N/m³ without weed-barrier treatments during the growing season. The K⁺ levels in the Prairie fertilizer treatment were lower than in the HighN fertilizer treatment in May ($p \leq 0.01$), July ($p \leq 0.05$), September ($p \leq 0.05$) and October ($p \leq 0.01$) (Table 8-8, Figure 8-8).

Correlation Analysis

Whole (un-ground) Media Leachate

The probability that the EC, nitrate and potassium are correlated is extremely high except for May values. When May values were removed from the analysis, the overall correlation for the growing season was extremely high for all paired combinations of EC, nitrate and potassium (Table 16). Regression analysis (with May values removed) yielded the same results with relatively high coefficient of determination (r^2) values for EC vs. nitrate and EC vs. potassium (Figures 8-9 – 8-11).

Ground Media Leachate

The probability that paired combinations for EC, nitrate and potassium are correlated is extremely high for both the by-month analysis and the combined growing season analyses (Table 16). Regression analysis confirms this result by yielding high coefficient of determination (r^2) values for all pair-wise regression analyses (Figure 8-12 – 8-14).

Discussion

The general rise in pH level of the pour-through leachate over the growing season was expected as the irrigation water has a relatively high pH and alkalinity levels (water quality evaluation from previous years' analysis: ADF #95000327). The pH trend nearly disappeared when the media was ground, resulting in the breaking up of the fertilizer capsules and bark both of which are acidic in nature.

Also expected was the linear decrease in pH and linear increase in EC, nitrate and potassium as fertilizer levels increased. The nutrient increases confirmed that fertilizer treatments were correctly applied. This was a concern as nutrient levels from month to month did not consistently decline, some months having higher levels than previous months. This may have pointed to instrument error except for the very high correlation among nutrient values (i.e. when nitrate was high, so was EC and potassium, each being measured by a different instrument). Nor does it necessarily point to sampling error, as variability within treatments was quite low (data not shown). At the moment, we are at a loss in explaining the month-to-month pattern.

Another point that is difficult to explain is the fact that fertilizer reserves remained high at the end of the season (as indicated by nutrient levels in the water extract leachate samples from the ground up media). According to the label, fertilizer longevity is 4 to 6 months, which means that in October, fertilizer levels should be very low to non-existent (nearing the same levels as the no-fertilizer treatment). It is possible that without plant involvement, nutrients are not as rapidly depleted as predicted. Another explanation is that since release is largely temperature dependent, release was much lower due to the unusually cooler summer temperatures that we experienced.

The weed-barrier provided some benefit aside from preventing weeds from landing on and germinating on the media surface. In the pour-through leachate samples, EC, nitrate and potassium levels were consistently higher in the weed-barrier containers than those of equivalent fertilizer levels without the weed-barrier. It is reasonable that the container media would be less prone to leaching with a weed barrier than without and nutrients would be available for plant growth for a longer period of time. In the ground-up media leachate samples, nitrate levels were significantly higher in the weed-barrier treatment later in the season (August – October) [EC and potassium levels were not significantly affected, but were numerically higher in the weed-barrier treatment than in the non-barrier treatment from August to October]. This would argue that the weed-barrier extended the longevity of the fertilizer and reduced environmental contamination by reducing leaching. The problem with this particular weed barrier is that it is not suitable for use with many herbaceous perennials due to its design (see Materials & Methods).

The Prairie blend fertilizer treatment leachate samples had consistently lower nutrient readings than the equivalent nitrogen rate (i.e. 1.2 kg N/m³) HighN fertilizer treatment samples. While all

care was taken in measuring and mixing the media and fertilizer together, it is possible that the fertilizer rate may have been incorrectly calculated or weighed out. Another explanation for the discrepancy is that the formulation on the bag was incorrect. There is no way at this time to assess which scenario is the correct explanation.

The correlation and regression analysis exploring the relatedness of the three nutrient assessments (EC, nitrate and potassium levels) revealed that in both the pour-through leachate (whole media) and the water extract (ground media) samples of any one of the nutrient tests could be used as a predictor for the other two with a high degree of confidence. Another season is required for confirm the utility of the regression equations and to develop a method of relating, say, ppm nitrate to fertilizer levels in terms that growers are more familiar with (i.e. pounds of fertilizer per cubic yard or kilograms fertilizer per cubic meter).

The end result of this trial will yield a method to assess soil-less media fertility levels quickly and accurately and to provide the results in terms that growers can incorporate into their management strategy. [NOTE: this trial was not continued in 2000. All experiments were re-evaluated to streamline efforts and to reduce variability]

Table 8-1. pH levels of pourthrough leachate of Dutch Growers bark-based media over the 1999 growing season

Treatment		May pH	June pH	July pH	Aug. pH	Sept. pH	Oct. pH	linear [†] (M → O)
no fertilizer	A	5.89	6.24	7.21	6.75	7.46	7.28	**
1 lbN/yard ³	B	6.15	6.53	7.08	6.63	6.93	7.13	**
2 lbN/yard ³	C	6.20	6.14	6.41	6.66	7.05	6.73	*
3 lbN/yard ³	D	6.13	6.27	4.87	6.15	6.75	6.14	ns
standard	E	4.78	5.73	6.43	6.70	6.91	6.83	**
barrier + 2 lbN/yard ³	F	6.21	6.36	6.99	6.79	6.92	7.00	**
PrairieBlend (2 lbN/yard ³)	G	5.92	6.40	6.61	6.75	7.27	6.92	**
Statistical Analysis								
significance [†]		**	**	**	**	*	**	
LSD		0.20	0.29	1.39	0.43	0.39	1.45	
Contrasts								
linear [†] (A,B,C,D)		*	ns	**	**	**	*	
quadratic [†] (A,B,C,D)		*	ns	+	+	ns	ns	
C vs F [†]		ns	*	ns	ns	ns	ns	
C vs G [†]		**	*	ns	ns	ns	ns	
CV%		2.68	2.70	12.17	3.73	4.23	12.10	

[†] ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

[‡] this column indicates whether there is a linear change in pH over time (May → October = M → O)

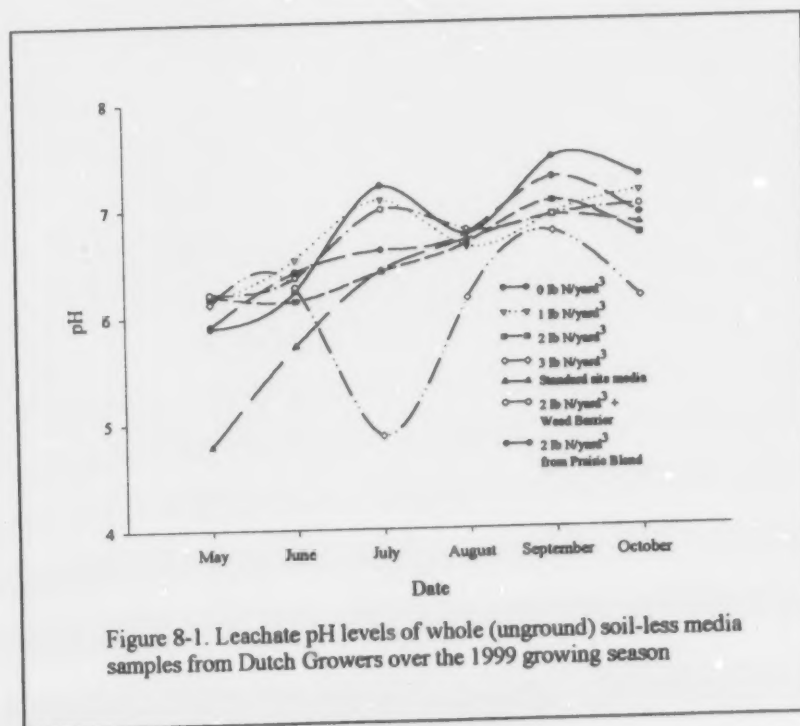


Table 8-2. EC levels of pourthrough leachate of Dutch Growers bark-based media over the 1999 growing season

Treatment		May mS/cm	June mS/cm	July mS/cm	August mS/cm	September mS/cm	October mS/cm
no fertilizer	A	129	35	208	16	47.5	16
1 lbN/yard ³	B	528	205	230	20	64	174
2 lbN/yard ³	C	916	318	270	48	124	428
3 lbN/yard ³	D	1147	284	586	112	184	500
standard	E	5400	244	420	112	136	288
barrier + 2 lbN/yard ³	F	938	664	470	326	220	616
PrairieBlend (2 lbN/yard ³)	G	660	273	368	116	116	382.5
Statistical Analysis							
significance [†]		**	**	**	**	**	**
LSD		409	270	238	136	95	164
Contrasts							
linear [†] (A,B,C,D)		**	**	**	+	**	**
quadratic [†] (A,B,C,D)		ns	ns	*	ns	ns	ns
C vs F [†]		ns	**	*	**	**	**
C vs G [†]		+	ns	ns	ns	ns	ns
CV%		24.4	53.4	37.4	72.6	42.9	26.3

† ns, +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

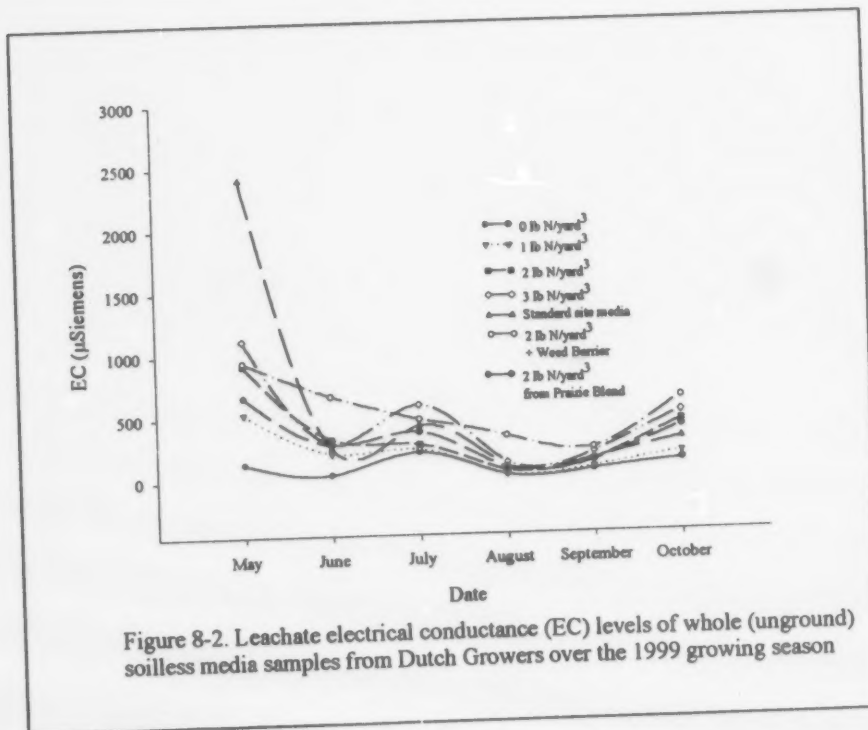


Table 8-3. Nitrate levels of pourthrough leachate of Dutch Growers bark-based media over the 1999 growing season

Treatment		May ppm	June ppm	July ppm	August ppm	September ppm	October ppm
no fertilizer	A	57	39	25	27	37	23
1 lbN/yard ³	B	117	76	120	34	71	66
2 lbN/yard ³	C	228	179	160	41	94	196
3 lbN/yard ³	D	276	205	223	76	164	248
standard	E	244	49	98	22	146	170
barrier + 2 lbN/yard ³	F	167	389	188	119	220	280
PrairieBlend (2 lbN/yard ³)	G	540	243	190	38	152	200
Statistical Analysis							
significance [†]		**	**	**	**	**	**
LSD		93	107	116	56	67	64
Constrasts							
linear [†] (A,B,C,D)		**	**	**	*	**	**
quadratic [†] (A,B,C,D)		ns	ns	ns	ns	ns	ns
C vs F [†]		+	*	ns	**	**	**
C vs G [†]		**	ns	ns	ns	*	ns
CV%		23.0	36.5	46.4	63.5	30.5	21.6

[†] ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

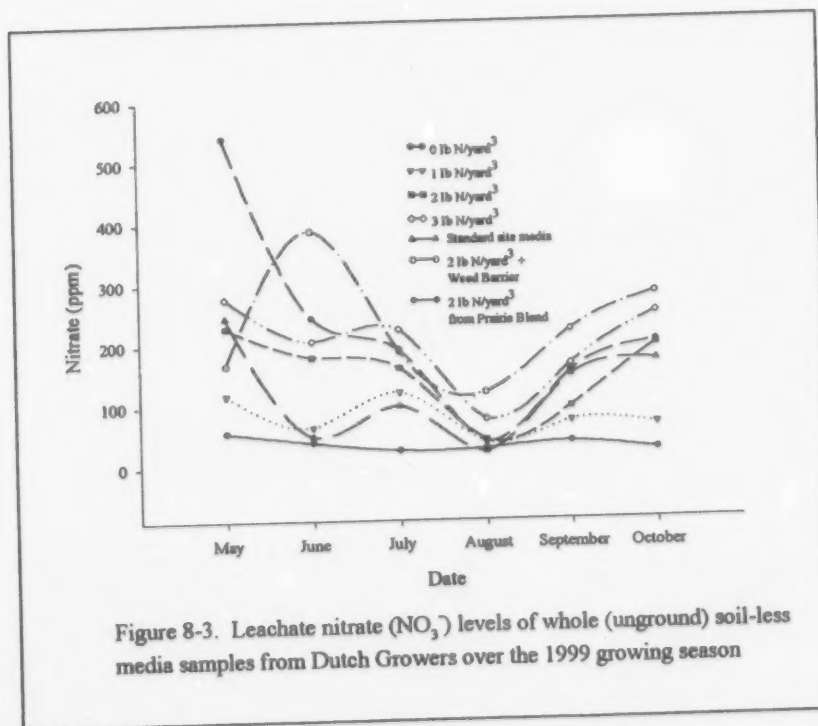


Table 8-4. Potassium levels of pourthrough leachate of Dutch Growers bark-based media over the 1999 growing season

Treatment		May ppm	June ppm	July ppm	August ppm	September ppm	October ppm
no fertilizer	A	17	10	10	4	6	6
1 lbN/yard ³	B	50	20	20	7	10	11
2 lbN/yard ³	C	52	22	13	5	10	17
3 lbN/yard ³	D	49	21	21	6	14	20
standard	E	82	21	20	6	14	13
barrier + 2 lbN/yard ³	F	60	30	22	14	14	22
PrairieBlend (2 lbN/yard ³)	G	34	17	20	4	9	14
Statistical Analysis							
significance†		**	**	ns	**	*	**
LSD		17	12	-	7	6	6
Constrasts							
linear† (A,B,C,D)		**✓	*	+	ns	*	**
quadratic† (A,B,C,D)		**	+	ns	ns	ns	ns
C vs F†		ns	+	+	**	+	*
C vs G†		**	ns	ns	ns	ns	+
CV%		19.2	32.9	41.2	50.4	38.8	22.0

† ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

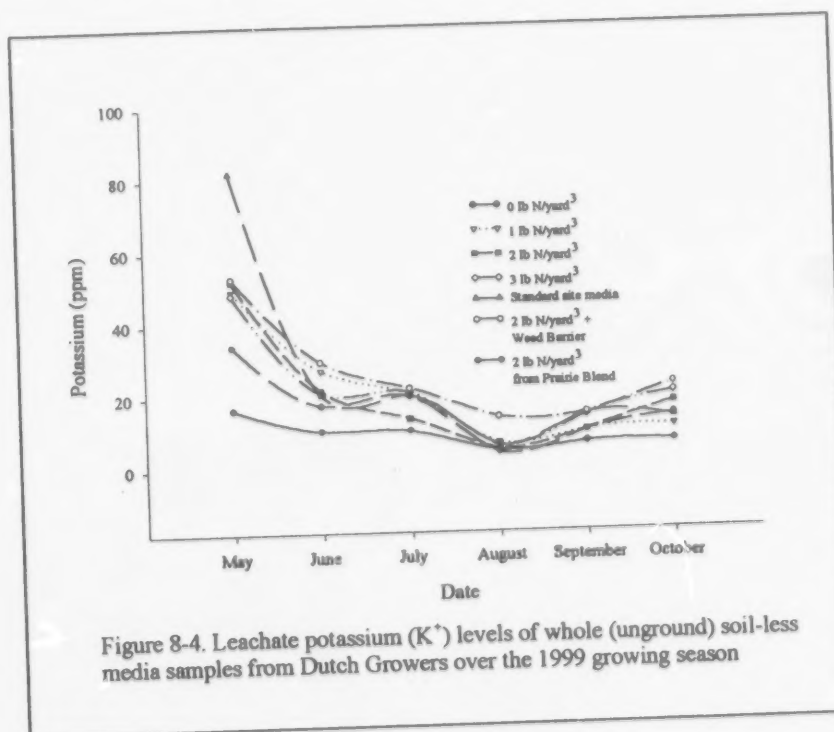


Table 8-5. pH levels of water extract from Dutch Growers ground-up bark-based media over the 1999 growing season

Treatment		May pH	June pH	July pH	Aug pH	Sept pH	Oct pH	linear† (M → O)
no fertilizer	A	6.85	6.12	6.58	7.29	6.56	6.76	*
1 lbN/yard ³	B	6.94	5.66	7.01	8.35	6.14	6.51	ns
2 lbN/yard ³	C	6.71	5.45	6.91	7.98	6.01	6.03	ns
3 lbN/yard ³	D	5.84	5.52	6.19	7.62	5.55	5.65	ns
standard	E	4.88	5.45	6.78	7.21	5.89	5.91	**
barrier + 2 lbN/yard ³	F	6.64	5.52	6.83	7.47	5.60	5.64	*
PrairieBlend (2 lbN/yard ³)	G	6.37	5.79	7.06	7.95	6.00	5.99	ns
Statistical Analysis								
significance†		**	**	**	**	**	**	
LSD		1.01	0.38	0.40	0.70	0.46	0.38	
Contrasts								
linear† (A,B,C,D)		**	**	*	ns	**	**	
quadratic† (A,B,C,D)		+	*	**	**	ns	ns	
C vs F†		ns	ns	ns	+	*	**	
C vs G†		ns	*	ns	ns	ns	ns	
CV%		9.1	3.8	3.4	5.1	4.4	3.6	

† ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01 , respectively
† this column indicates whether there is a linear change in pH over time (May → October = M → O)

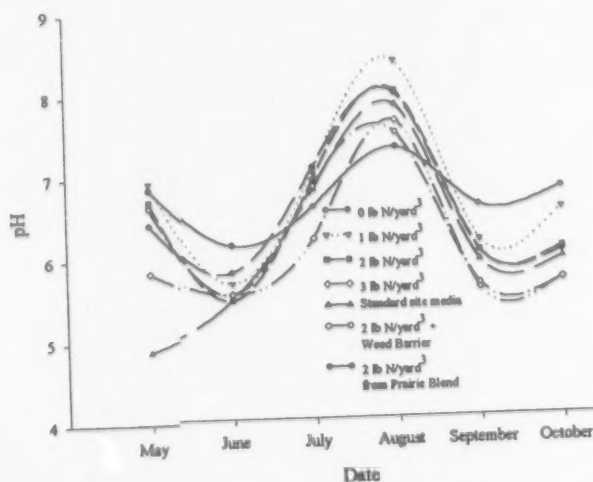


Figure 8-5. Leachate pH levels of ground soil-less media samples from Dutch Growers over the 1999 growing season

Table 8-6. EC levels of water extract from Dutch Growers ground-up bark-based media over the 1999 growing season

Treatment		May mS/cm	June mS/cm	July mS/cm	Aug. mS/cm	Sept. mS/cm	Oct. mS/cm	linear† (M → O)
no fertilizer	A	326	288	318	208	360	430	*
1 lbN/yard³	B	4400	3040	4180	2322	3180	2602	**
2 lbN/yard³	C	8180	8220	7760	4638	5940	6360	+
3 lbN/yard³	D	8860	8460	11560	6420	7800	6220	*
standard	E	6760	5900	4580	4160	4680	4040	**
barrier + 2 lbN/yard³	F	7260	10000	7520	6340	7000	7220	ns
PrairieBlend (2 lbN/yard³)	G	3960	6060	5500	4520	4040	4425	ns
Statistical Analysis								
significance†		**	**	**	**	**	**	
LSD		3364	4285	2903	2940	2282	1896	
Constrasts								
linear† (A,B,C,D)		**	**	**	**	**	**	
quadratic† (A,B,C,D)		+	ns	ns	ns	ns	*	
C vs F†		ns	ns	ns	ns	ns	ns	
C vs G†		**	ns	*	ns	*	**	
CV%		33.9	40.9	28.1	41.2	27.7	24.3	

† ns, +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01 , respectively
† this column indicates whether there is a linear change in pH over time (May → October = M → O)

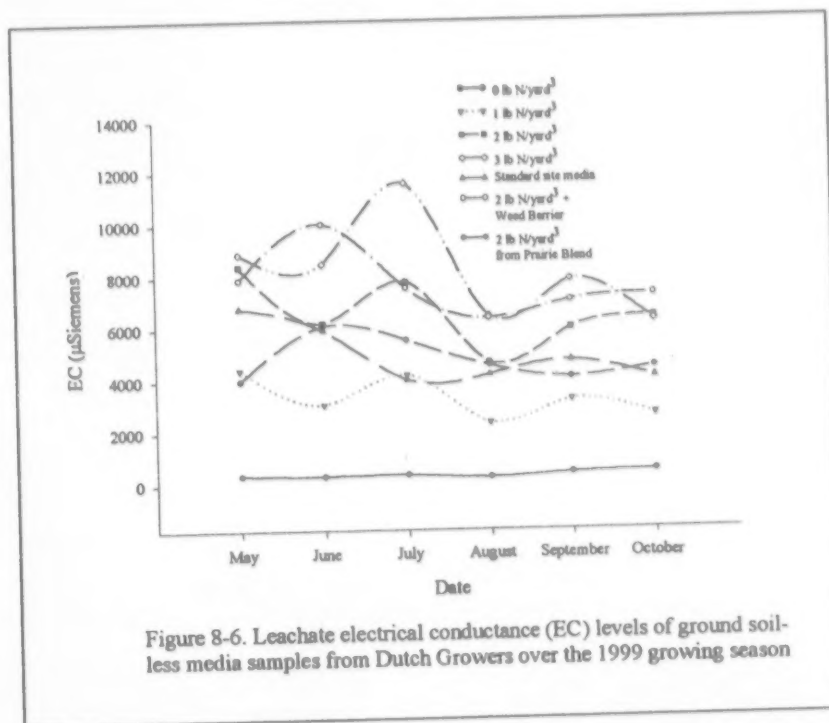


Table 8-7. Nitrate levels of water extract from Dutch Growers ground-up bark-based media over the 1999 growing season

Treatment		May ppm	June ppm	July ppm	Aug. ppm	Sept. ppm	Oct. ppm	linear [†] (M → O)
no fertilizer	A	230	328	110	111	165	164	**
1 lbN/yard ³	B	1760	1300	1142	860	1096	874	**
2 lbN/yard ³	C	3220	4240	2440	1808	2120	2080	**
3 lbN/yard ³	D	3340	4400	3880	2620	1460	2260	**
standard	E	2540	2480	1440	1800	1460	1520	**
barrier + 2 lbN/yard ³	F	2500	4220	2540	2840	2520	2640	ns
PrairieBlend (2 lbN/yard ³)	G	1480	2600	1740	2220	1460	1650	ns
Statistical Analysis								
significance [†]		**	**	**	**	**	**	
LSD		1111	2012	1012	1065	777	646	
Constrasts								
linear [†] (A,B,C,D)		**	**	**	**	**✓	**	
quadratic [†] (A,B,C,D)		+	ns	ns	ns	**	ns	
C vs F [†]		ns	ns	ns	*	ns	*	
C vs G [†]		**	*	+	ns	*	+	
CV%		29.5	41.2	30.5	34.8	30.3	23.1	

† ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

‡ this column indicates whether there is a linear change in pH over time (May → October = M → O)

Table 8-8. Potassium levels of water extract from Dutch Growers ground-up bark-based media over the 1999 growing season

Treatment		May ppm	June ppm	July ppm	August ppm	Sept. ppm	Oct. ppm	linear† (M → O)
no fertilizer	A	32	29	20	13	13	16	**
1 lbN/yard ³	B	234	200	222	129	170	132	**
2 lbN/yard ³	C	490	496	386	244	338	352	*
3 lbN/yard ³	D	498	508	606	368	456	410	ns
standard	E	382	318	238	220	260	248	**
barrier + 2 lbN/yard ³	F	446	556	380	354	408	428	ns
PrairieBlend (2 lbN/yard ³)	G	194	630	270	238	204	235	ns
Statistical Analysis								
significance†		**	**	**	**	**	**	
LSD		205	256	150	176	154	114	
Constrasts								
linear† (A,B,C,D)		**	**	**	**	**	**	
quadratic† (A,B,C,D)		+	ns	ns	ns	ns	ns	
C vs F†		ns	ns	ns	+	ns	+	
C vs G†		**	ns	*	ns	*	**	
CV%		36.0	41.5	28.4	45.1	33.5	25.2	

† ns, +, * and ** = not significant, significant at $p \leq 0.10$, 0.05 and 0.01, respectively

‡ this column indicates whether there is a linear change in pH over time (May → October = M → O)

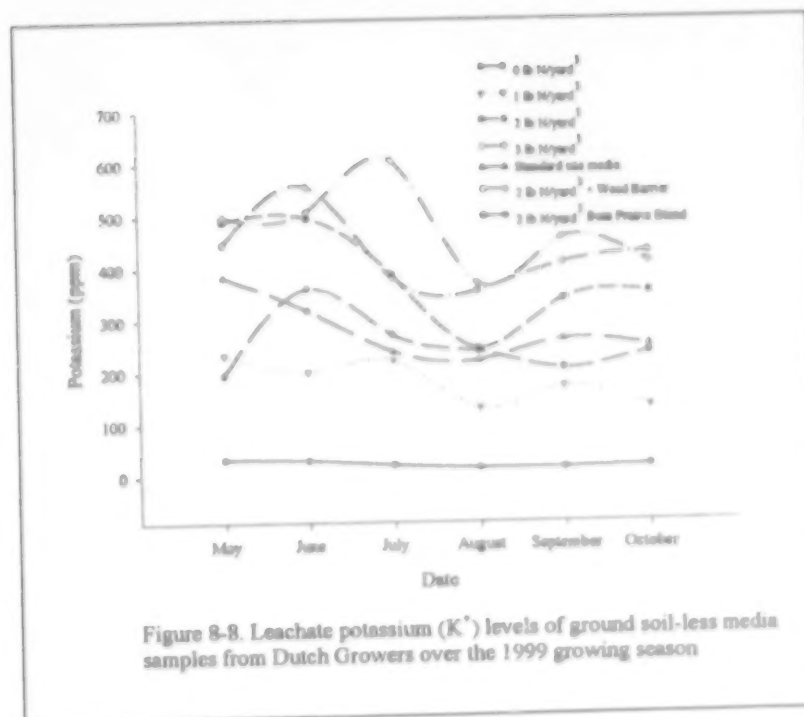


Table 8-9. Correlation (Pearson's) and probability of all pair-wise combinations of electrical conductivity (EC), nitrate (NO_3^-) and potassium (K^+) levels from leachate samples from both ground and whole media samples over the 1999 growing season.

potassium (K ⁺) levels from leachate samples from both ground and whole media samples over the 1999		1999		1999		1999		1999	
Whole media leachate	May Corr. coeff (prob) [†]	June Corr. coeff (prob) [†]	July Corr. coeff (prob) [†]	August Corr. coeff (prob) [†]	September Corr. coeff (prob) [†]	October Corr. coeff (prob) [†]	(May-Oct) Corr. coeff (prob) [†]	(June-Oct) Corr. coeff (prob) [†]	
EC vs NO ₃ ⁻	0.245 (0.155)	0.879 (0.000)	0.803 (0.000)	0.873 (0.000)	0.924 (0.000)	0.957 (0.000)	0.566 (0.000)	0.840 (0.000)	
EC vs K ⁺	0.866 (0.000)	0.939 (0.000)	0.746 (0.000)	0.783 (0.000)	0.842 (0.000)	0.943 (0.000)	0.902 (0.000)	0.836 (0.000)	
NO ₃ ⁻ vs K ⁺	0.114 (0.513)	0.716 (0.000)	0.724 (0.000)	0.851 (0.000)	0.765 (0.000)	0.914 (0.000)	0.533 (0.000)	0.774 (0.000)	
Ground media leachate									
EC vs NO ₃ ⁻	0.975 (0.000)	0.980 (0.000)	0.994 (0.000)	0.983 (0.000)	0.808 (0.000)	0.960 (0.000)	0.929 (0.000)		
EC vs K ⁺	0.982 (0.000)	0.995 (0.000)	0.998 (0.000)	0.996 (0.000)	0.995 (0.000)	0.949 (0.000)	0.984 (0.000)		
NO ₃ ⁻ vs K ⁺	0.966 (0.000)	0.987 (0.000)	0.993 (0.000)	0.975 (0.000)	0.793 (0.000)	0.987 (0.000)	0.934 (0.000)		

† - the top number of each pair is Pearson's correlation coefficient; the number in brackets is the probability (p) that the two characteristics are related

ADF #97000283: Improving Nursery Production of Container Grown Herbaceous Perennials:
January 2002 Final Report

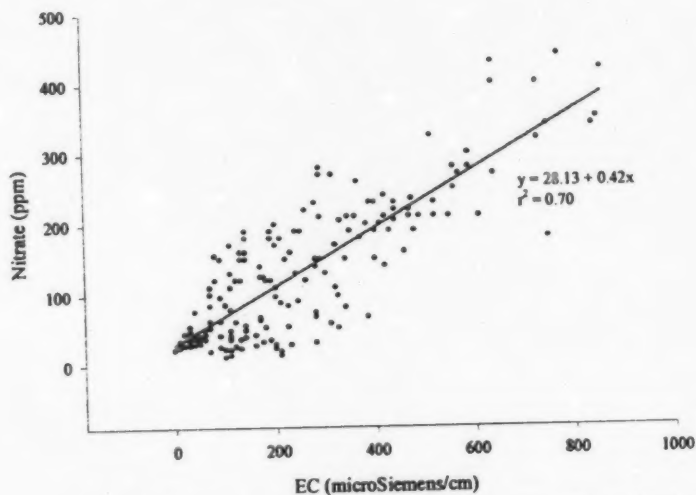


Figure 8-9. Electrical conductivity vs. nitrate concentration of leachate from whole media over the 1999 growing season (June - October)

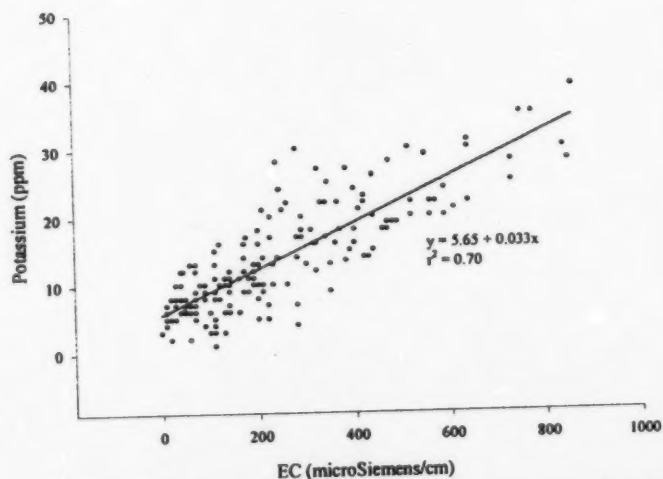


Figure 8-10. Electrical conductivity vs potassium concentration of leachate from whole media over the 1999 growing season (June - October)

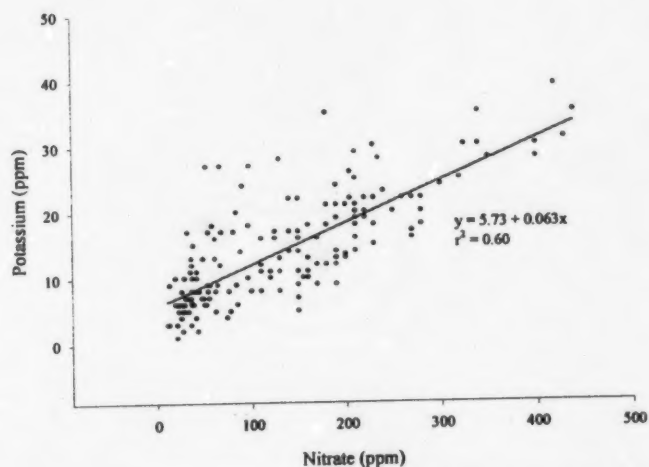


Figure 8-11. Nitrate concentration vs. potassium concentration of leachate from whole media over the 1999 growing season (June - October)

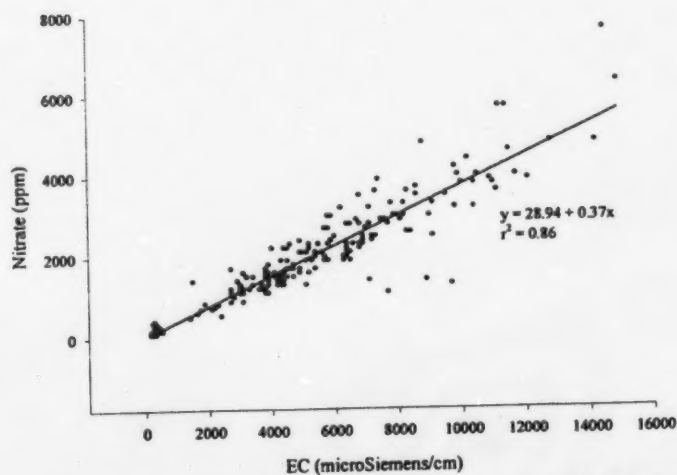


Figure 8-12. Electrical conductivity vs. nitrate concentration of water extracts from ground media over the 1999 growing season (May - October)

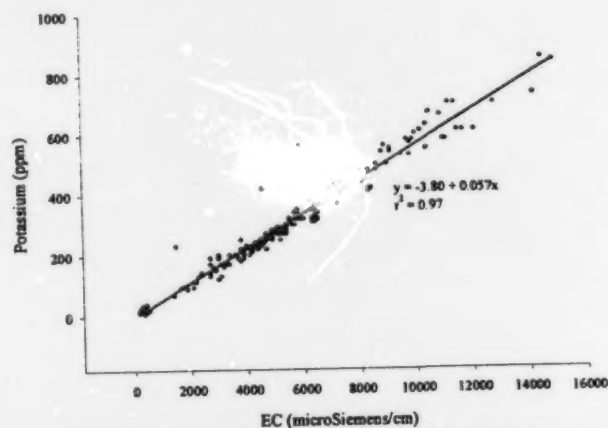


Figure 8-13. Electrical conductivity vs. potassium concentration of water extract from ground media over the 1999 growing season (May - October)

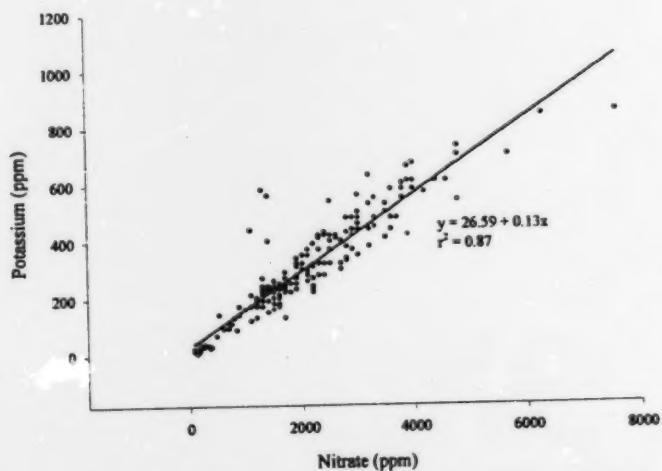


Figure 8-14. Nitrate concentration vs. potassium concentration of water extract from ground media over the 1999 growing season (May - October)

Perennial Literature Collection

A number of journal articles (96) and a few books that pertain to perennial plant production have been acquired. The references were catalogued using a computer-based reference manager (EndNote, Niles Software Inc., Berkley, CA). These references have incorporated into the Nursery Production Literature Collection (NPLC), a collection that contains over 1200 articles.

The number prefixing each reference is a unique record number assigned to each entry in the database. This number allows quick retrieval of articles from the NPLC. Copies of papers can be made for interested growers (and others) at some minimal cost per article to recover the cost of reproduction and postage. The NPLC is currently housed at the Department of Plant Sciences, University of Saskatchewan so horticulture students and researchers may also have access to the collection.

The articles specific to herbaceous perennials follow:

(1076)

Abraham, V. and B. M. Desai (1977). Induced tetraploidy in a perennial *Portulaca* mutant. *Indian Journal of Horticulture* 34(3): 301-305.
When cuttings of a gamma-ray induced 5-petal mutant of portulaca were treated with colchicine at 0.05% for 36 h some tetraploid branches with larger flowers were produced. Data are presented on the vegetative and floral characteristics of the tetraploid compared with the diploid plants.

(627)

Aderhold, A. and J. Kuhn (1991). *Scabiosa caucasica* - a profitable cut-flower perennial. *Gartenbau Magazin* 38(10): 48-49.
From trials conducted in Berlin, recommendations are made for the field cultivation of S. caucasica. Plants should be divided in Apr. or mid-Aug. and planted in deep, rich soil of pH 6.4-6.8. Basal and supplementary doses of fertilizer should be given, and the plants should be watered in dry weather but not allowed to become waterlogged. The flowers can be harvested 2-3 times/week between mid-June and late Oct. and yields of 50-60 stems/plant can be expected by the third year. The harvest should not begin until 10-12 weeks after planting out. Good cultivars are Blausiegel, Clive Greeves and Miss Willmott.

(512)

Ahrens, J. F. (1983). Postemergence grass herbicides for woody ornamentals and Christmas trees. Proceedings of the 37th annual meeting of the Northeastern Weed Science Society 318: 318.
In nursery trials, 0.25-1.5 lb fluazifop-butyl or sethoxydim/ac controlled a number of annual and perennial grasses and volunteer rye selectively in a wide range of evergreen ornamentals including some broadleaved spp. Selectivity was uncertain in actively growing forsythia and some azalea cv. Combinations with oxyfluorfen extended post-em. control to many broadleaved weeds. In Christmas trees, combinations with simazine and/or oryzalin were also effective.

(1204)

Ahrens, J. F. (1981). Preemergence herbicides for transplanted herbaceous perennials. *Northeastern Weed Science Society, Proceedings* 35: 267 - 272.

(1254)

Allenstein, P., A. M. Richards, et al. (1987). Growing perennials. *Ext Bull E Coop Ext Serv Mich State Univ Mich.* (The Service. Mar 1987. (1984) 28 p. ill.): 28 pp.

(1236)

Anderson, N. O., P. D. Ascher, et al. (1990). Rapid generation cycling of chrysanthemum using laboratory seed development and embryo rescue techniques. *Journal of the American Society for Horticultural Science* 115(2): 329-336.
The generation time (0.75 to 1.5 years) in perennial hexaploid chrysanthemums impedes the rate of progress of sexual breeding programmes aimed at creating new clonal cultivars, inbred lines for hybrid seed production, and germplasm for genetic studies. Modifications to the crossing environment and embryo rescue were evaluated to minimize the generation cycle. One greenhouse chrysanthemum clone was outcross-pollinated using a bulk pollen source. Following emasculation, inflorescences were either left in situ or the peduncle bases were placed in styrofoam boards floating on a solution of 1% sucrose and 200 p.p.m. 8-hydroxyquinoline citrate under laboratory conditions. Embryogenesis occurred at a faster rate under laboratory conditions as tested with histological techniques; the heart stage appeared as early as the second day after pollination, compared with 11 days using in situ methods. Total embryogenic development time ranged from 25 (laboratory seed development) to 52+ days (in situ ripening). In a second test, embryo rescue (ER) significantly improved percent seed set, percent germination, and percent of progeny reaching anthesis relative to normal development. ER progeny from female parents of the garden chrysanthemum cultivars Royal Knight and Royal Pomp were significantly earlier in total generation time than corresponding non-ER siblings. Laboratory seed development and ER were then used sequentially to obtain an average progeny generation time of 100 days, thus allowing for 3 generations per year. The potential impact of these 2 techniques on breeding chrysanthemums and other perennial crops with long generation times is discussed.

(1009)

Anon. (1996). *???? Nursery Management and Production* (August): 30 - 32, 34 - 35, 37.

(1055)

Armitage, A. M. The influence of spacing on field-grown perennial crops. *HortScience* 22(5): 904-907.
Achillea cv. Coronation Gold, A. millefolium cv. Rose Beauty, Physostegia virginiana, Liatris pycnostachya and Salvia leucantha were planted 30-, 60-, 90- or 120-cm apart. Data were collected for 2 or 3 years, depending on species. In all

instances the number of flowering stems/plant increased but the number of stems/m² decreased as spacing increased. Stem lengths of Coronation Gold, Rose Beauty and *P. virginiana* were affected significantly by spacing (short and medium stems increasing in length with wider spacing and long stems decreasing in length) whereas flower size and stem diameter remained unchanged.

(1135)

Armitage, A. M. (1987). *Achillea*. A common perennial offers uncommonly attractive characteristics. *American Nurseryman* 166(7): 94-99, 103.

A discussion of ornamental *Achillea* species and cultivars suitable for growing in various parts of the USA, with detailed descriptions of *A. X Coronation Gold*, *A. filipendulina*, *A. grandifolia*, *A. millefolium*, *A. X Moonshine*, *A. ptarmica* and *A. tomentosa*.

(633) Record April 18, 1999

Armitage, A. M. (1996). Forcing of perennials in the greenhouse: A guide to putting flowers and buds on perennials (based on research at UGA). 1999.

Perennials have undergone a major expansion in North America and sales have significantly increased in the last 10 years. The classical nursery grower of perennials produced crops in large containers outdoors which were overwintered for spring sales. Plants were often sold green and the presence of flowers was welcome, but not necessary. The market for perennials has expanded to include sales of non cooled plants in the fall, non cooled plants in the spring, and cooled plants in the spring in smaller containers for gardeners and landscapers. In general, the growing of perennials has been done by the nursery person while the greenhouse operator has concentrated on producing "color plants".

Times are a-changing! The renewed interest in perennials by the garden and landscape public has finally provided the greenhouse operator the kick in the pants he needed to look more closely at perennials. The greenhouse industry was so busy growing a better petunia that they overlooked the beauty of the columbine and the romance of the forget-me-not. However, the difficulty for the greenhouse person was multifold. First, compared with annuals, the number of potential species is overwhelming. Every new book on perennials and every talk on perennials offers more potential plants than the bedding plant or pot plant grower

ever dreamed about.

(1137)

Armitage, A. M. (1987). Spacing of field grown perennial crops - an interim report. *Acta Horticulturae* No. 205: 149-150.
Achillea cv. Coronation Gold, *A. millefolium* cv. Rose Beauty, and *Physostegia virginiana* for cut flowers were planted 30, 60, 90 or 120 cm apart; Data were collected for 2 or 3 years depending on species. In all cases the number of flowering stems/plant increased but the number of stems/m² decreased as spacing increased. Stem lengths of Coronation Gold, Rose Beauty and *P. virginiana* were significantly affected by spacing (numbers of medium-length stems increased, and of long stems decreased with planting distance) but flower size and stem diameter remained unchanged.

(1193)

Armitage, A. M., J. A. Considine, et al. (1998). Protocols for evaluating new crops: the new crop program at the University of Georgia. Proceedings of the third international symposium on new floricultural crops, Perth, Western Australia, 14 October 1996 No. 454: 251-262.

This programme has been established for about 10 years. Crops are studied with potential as indoor flowering pot plants, potted flowering perennial plants, amenity plants or new cut flower crops. Less emphasis has been recently placed on flowering pot plant candidates. Protocols for selecting and eliminating crops from the programme are discussed and achievements noted.

(1239)

Armitage, A. M. and J. M. Garner (1999). Photoperiod and cooling duration influence growth and flowering of six herbaceous perennials. *Journal of Horticultural Science and Biotechnology* 74(2): 170-174.

In a trial carried out in 1993-94, seedlings of 6 herbaceous perennials were subjected to 0, 4, 8 or 12 weeks of cold treatment at 2-3°C followed by long- or short-day photoperiods after the cold treatment. Cold was not necessary for flowering in any of the taxa studied, but the duration of cold treatment was inversely related to forcing-phase days to flower for all taxa. Plant height at flowering increased due to cooling in *Myosotis scorpioides* cv. Victoria Rose and *Campamula carpatica* cv. Blue Chips while decreasing in *Anchusa capensis* cv. Blue Angel. In *M. scorpioides*, the number of growing points also decreased as cooling duration increased. Photoperiod influenced flowering time in 4 taxa

but not in *M. scorpioides* and *Arabis blepharophylla* cv. Spring Charm. Flower stems of *M. scorpioides* and *A. capensis* elongated more in long days than in short days. Short days reduced internode elongation in *Gypsophila repens* and inhibited flowering of *C. carpatica* and *Catananche caerulea*. Taxa were classified as day neutral, quantitative long day or qualitative long day plants.

(872)

Armitage, A. M. and P. M. Gross (1996). Copper-treated plug flats influence root growth and flowering of bedding plants. *HortScience* 31(6): 941-943.

A copper hydroxide formulation (0, 3.5, 7 or 11% Cu) was applied to plug trays before sowing seeds of *Impatiens* [walleriana] cv. Accent Red, *Pelargonium Xhortorum* cv. Scarlet Elite and *Petunia Xhybrida* cv. Ultra White to investigate the influence of the formulations on ease of transplanting, root growth and shoot growth. These factors were also investigated in Cu-treated seedling plugs held past the optimal transplanting stage. Root spiralling and seedling height at transplanting were reduced for all taxa grown in Cu-treated trays, at all concentrations, compared with seedlings from non-treated trays. Root weight and shoot weight responses to Cu treatments at transplanting and at flowering varied among taxa. Mature heights of all taxa were unaffected by Cu treatment; however, flowering date was delayed for *impatiens* and *pelargoniums* transplanted at the optimal time from Cu-treated trays. In general, *petunias* displayed little response to Cu treatment. Root spiralling was reduced and plugs were removed more easily from Cu-treated than from control trays stored for 2 weeks in the greenhouse, but flowering time was delayed by 12 days for *impatiens* and *petunias* and 21 days for *geraniums*, regardless of Cu concentration.

(866)

Arnold, M. A., D. L. Airhart, et al. (1993). Cupric hydroxide-treated containers affect growth and flowering of annual and perennial bedding plants. *Journal of Environmental Horticulture* 11(3): 106-110.

Cultivars of 4 annual species (*Celosia cristata* [C. argentea var. cristata] cv. Castle Pink, *Impatiens walleriana* cv. Super Elfin Red, *Pelargonium X domesticum* cv. Ringo Scarlet and *Tagetes patula* cv. Discovery Yellow) and 2 perennial species (*Chrysanthemum* [Leucanthemum] X *superbum* cv. Alaska and *Coreopsis lanceolata* cv. Early Sunrise) were grown in a greenhouse for about 40

days in 0.3-litre plastic containers that had been treated on their inner surfaces with 25, 50 or 100 g Cu(OH)₂/litre, formulated as Spin Out. Control plants were grown in untreated containers.

Following greenhouse production and a 4-day acclimatization period in a shade-house, the plants were transplanted to a field plot. Cupric hydroxide concentrations that resulted in practical levels of control and/or elimination of root deformation (circled, kinked and matted roots at container wall/media interfaces) were species-dependent; 100 g/litre reduced, but did not eliminate, root deformation in *T. patula* and *L. superbum*, whereas 25 g/litre almost completely eliminated root deformation in *P. domesticum*. During greenhouse production, Cu(OH)₂ treatments of 50 or 100 g/litre increased the vegetative growth of *C. cristata* and increased the number of flowers on *I. walleriana*, compared with controls. After field planting, *P. domesticum* grown in 50 or 100 g Cu(OH)₂/litre-treated containers and *I. walleriana* in 100 g Cu(OH)₂/litre-treated containers had increased vegetative growth, compared with controls. The flowering potential of *I. walleriana* following field planting was increased by the 50 g Cu(OH)₂/litre treatment.

(1170)

Ashman, T. L. (1994). A dynamic perspective on the physiological cost of reproduction in plants. *American Naturalist* 144(2): 300-316.

The physiological cost of reproduction was investigated in a greenhouse population of the perennial species *Sidalcea oregana* subsp. *spicata*. Two classes of estimates of current reproductive investment were compared, with the goal of identifying the most powerful predictor of future reproductive effort. Static estimates, those typically used to measure current reproductive investment (i.e., biomass or nutrients allocated to reproduction), neglect the physiological processes that influence actual reproductive expenditure. Conversely, dynamic estimates that incorporate reproductive photosynthesis or respiration, nectar production, or reproductive nutrient resorption offer a more accurate assessment of current reproductive investment. The potential was assessed for nutrient resorption from senescing reproductive structures to mitigate the cost of reproduction. Significant proportions of nitrogen and phosphorus were resorbed from floral structures, but structures differed in resorption potential and efficiency. Moreover, dynamic estimates of nutrient investment were better predictors of future reproductive effort than were static estimates. Dynamic estimates appeared to be

closer indicators of realized physiological cost of reproduction. By taking a dynamic perspective of reproductive investment, the potential for evolutionary change in life history and sex allocation in plants may be better addressed.

(1181)

Bachmann, M., P. Matile, et al. (1994).

Metabolism of the raffinose family oligosaccharides in leaves of *Ajuga reptans* L. Cold acclimation, translocation, and sink to source transition: discovery of chain elongation enzyme. *Plant Physiology* 105(4): 1335-1345.

A. reptans is a frost-hardy, perennial labiate known for its high content of raffinose family oligosaccharide(s) (RFO). Seasonal variations in soluble non-structural carbohydrate levels in above-ground parts showed that the RFO were the predominant components throughout the whole year. RFO concentrations were lowest in summer (75 mg/g FW) and highest in autumn/winter (200 mg/g FW), whereas sucrose and starch were only minor components. Cold treatment (14 days at 10/3°C, day/night) of plants that were precultivated under warm conditions (25°C) lowered the temperature optimum of net photosynthesis from 16 to 8°C, decreased the maximum rate and increased the total non-structural carbohydrate content of leaves by a factor of about 10, mainly because of an increase of RFO. The degree of polymerization of the RFO increased sequentially up to at least 15. A novel, galactinol-independent galactosyltransferase enzyme was found, which, from 2 molecules of RFO, formed the next higher and lower degree of polymerization of RFO. The enzyme had a pH optimum of 4.5-5.0 and may be responsible for RFO chain elongation. RFO were the main carbohydrates translocated in the phloem, with stachyose being by far the most dominant form. Studies of carbon balance during leaf development revealed a transition point between import and export at approx. 25% maximal leaf area. RFO synthesis could be detected even before the start of export, suggesting the existence of a non-phloem-linked RFO pool even in very young leaves. Taken together, it seems that *A. reptans* leaves contain 2 pools of RFO metabolism, a pronounced long-term storage pool in the mesophyll, possibly also involved in frost resistance, and a transport pool in the phloem.

(654)

Bale, S. (1988). An annual or a perennial. *HO Univ Ky Coll Agr Coop Ext Serv*(65): 19.

(1070)

Banovetz, S. J. and S. M. Scheiner (1994). Secondary seed dormancy in *Coreopsis lanceolata*. *American Midland Naturalist* 131(1): 75-83.

The physical and physiological factors that control germination in the herbaceous perennial, *Coreopsis lanceolata* (Asteraceae) were examined. Seeds stored in paper envelopes for 6-18 months at room temperature were tested for germination on moistened filter paper in Petri dishes. Germination percentages were greatest at 15° and 25°C and 12-h light/dark cycles. Germination percentages of imbibed seeds were not affected by previous storage at -10°. Imbibed seeds subjected to 5° entered a secondary dormancy that could not be broken by subsequent warmer temperatures, light/dark cycles or freezing temperatures. Secondary dormancy in *C. lanceolata* may be a mechanism for spreading the risk of recruitment.

(1187)

Baskin, C. C. and J. M. Baskin (1988).

Germination ecophysiology of herbaceous plant species in a temperate region. *American Journal of Botany* 75(2): 286-305.

Germination phenology data were collected from 75 winter annuals, 49 summer annuals, 28 monocarpic perennials and 122 polycarpic perennials, and experimental investigations of dormancy breaking and germination requirements were conducted on 56 winter annuals, 32 summer annuals, 18 monocarpic perennials and 73 polycarpic perennials, in order to determine any correlations between the dormancy breaking and germination requirements of seeds and the germination phenology, life cycle type, habitat requirements, range of geographical distribution and phylogenetic relationships of the species. Plants studied included ornamental and weed species. Germination phenology was highly correlated with the responses of seeds to the yearly temperature cycle. Species with winter and summer annual life cycles had predictable germination characteristics, but monocarpic and polycarpic perennials did not. Several dormancy types could be found in a given habitat, and narrowly endemic and widely-distributed species in the same genus sometimes had similar germination characteristics. Within some families there was a tendency for a particular type of seed-temperature response to be very important, but frequently this was related to the predominance of a given life cycle type in the family.

(596)

Beattie, D. J. (2000). Timing is everything. *American Nurseryman*(February 15): 28 - 30, 32 -

34.

Understanding propagation timing of perennials can help growers get their plants to customers within the desired sales window

(655)

Beattie, D. J. (1986). Profiting from perennials: how to start a perennial business. *Am Nurseryman* 164(9): 81-82, 86-92, 94-98, 100-102.

(1241)

Beattie, D. J., R. M. Herman, et al. (1993). Unraveling the mystery. *Am nurseryman* 178(7): 40-49.

(1104)

Beckstrom-Sternberg, S. M., L. H. Rieseberg, et al. (1991). Gene lineage analysis in populations of *Helianthus niveus* and *H. petiolaris* (Asteraceae). *Plant Systematics and Evolution* 175(3-4): 125-138.
H. petiolaris and *H. niveus* are polytypic species which are morphologically distinct at the periphery of their ranges but intergrade in areas of sympatry. *H. niveus* includes both annual and perennial members, whereas *H. petiolaris* is strictly annual. *ctDNA* and nuclear ribosomal DNA restriction site data were used to reconstruct the evolutionary history of populations of the 2 species. Cladistic analyses revealed the following: (1) neither species is monophyletic; (2) the annual habit is derived once in this complex; and (3) the region of morphological intergradation appears to be primary in origin. The significance of interbreeding vs. common descent in defining species concepts is discussed in relation to the above cladistic analyses.

(662)

Behe, B. K. and L. Beckett (1991). Profile of the perennial plant industry. Research Report Series Alabama Agriculture Experimental Station Auburn University(7): 14-15.

(1127)

Bellardi, M. G., R. Credi, et al. (1985). Tobacco streak virus in *Clematis vitalba* L. *Phytopathologia Mediterranea* 24(3): 255-259.
Naturally infected plants of this perennial wild sp. showed yellow mosaic and vein yellowing. On the basis of host range, symptoms and particle characteristics, the pathogen was identified as TSV. In gel diffusion tests, it reacted with an antiserum to a N. American isolate of TSV.

(1194)

Benson, D. M. (1978). A direct versus a photographic technique as nondestructive estimates of growth response on perennial ornamentals affected with nematode decline. *Plant Disease Reporter* 62(1): 68-70.

Two nondestructive measurements of plant growth were compared for Buxus sempervirens var. globosum infected with Pratylenchus vulnus, Ilex crenata infected with Meloidogyne arenaria, and Ilex cornuta not showing nematode decline. Plants were harvested after 41 months in field microplots to determine top weight. Plant weight was regressed against either plant height X width product (direct technique) or plant image area (photographic technique) as measured in a standardized photograph. Highly significant correlations were found when either nondestructive technique was compared with weight on a log-log basis. The direct technique gave slightly better co-efficients of determination than the photographic technique when compared with weight. Nondestructive measurements of plant growth are particularly useful for studying time-dependent responses of perennial ornamentals where sacrificing plants for weight determination is impractical or uneconomical due to limitations of space or other resources. [AS] ADDITIONAL ABSTRACT: Two non-destructive measurements of plant growth were compared for Buxus sempervirens var. globosum infected with Pratylenchus vulnus, Ilex crenata infected with Meloidogyne arenaria and Ilex cornuta not showing nematode decline. After 41 months' growth, the plants were lifted and the above-ground parts weighed. The weights were regressed against the product of plant height X width (direct technique) and plant image area (photographic technique). Both non-destructive techniques gave highly significant correlations when compared with plant weight on a log-log basis, the direct technique giving slightly better coefficients of determination.

(1185)

Bertin, R. I. and M. A. Kerwin (1998). Floral sex ratios and gynomonoecy in Aster (Asteraceae). *American Journal of Botany* 85(2): 235-244.
Gynomonoecy is the sexual system in which female and bisexual flowers occur on the same plant. This system has received little attention despite the considerable work on other plant sexual systems in the past few decades. This study examines one hypothesized advantage of having two flower types on a plant, namely that this arrangement permits flexibility in allocation of resources to male and female reproductive functions. Some 16 species of

Aster, a genus of gynomonoecious, perennial herbs were studied. Plants in this genus produce heads consisting of a whorl of female flowers around a cluster of bisexual flowers. Among field-grown plants no evidence was found that plant size, date, position of heads, rainfall, or shade influenced the proportion of female flowers. A series of greenhouse experiments likewise revealed no large or consistent effects of light, nutrients, or position of heads on the proportion of ray florets. While floral ratios proved very stable in the face of environmental and physiological variables, they exhibited significant variation among plants and among sibships in most species. It is concluded that the presence of two flower types in gynomonoecious asters is not advantageous in permitting flexibility in allocation of resources to male and female functions. It is suggested that the advantage of the female flowers in aster heads lies either in reducing pollen-pistil interference or in attracting pollinators.

(293)

Beste, C. E. and J. R. Frank (1990). Influence of metolachlor on *Ilex crenata* Thunb. for control of yellow nutsedge. *Journal of Environmental Horticulture* 8(2): 58-60.

A single spring of fall application of Dual 8E (metolachlor) at 13.5 kg/ha to newly planted 'Hertzii' and 'Howardi' Japanese holly caused 15 to 18% injury during the first few weeks after treatment. No additional injury or reduced growth was evident with any Dual treatments 4 weeks after application. Applications of Dual at rates up to 13.5 kg/ha to established 'Hertzii' holly did not cause injury or affect plant height x width. Dual at 4.5 kg/ha to 13.5 kg/ha was adequate to control yellow nutsedge (*Cyperus esculentus* L.)

(901)

Bhat, N. R., T. L. Prince, et al. (1992). Rooted cutting establishment in media containing wetting agent. *HortScience* 27(1): 78.
Rooted cuttings of *chrysanthemum* cv. Bright Golden Anne, *Pelargonium* cv. Your's Truly, *Impatiens walleriana* and *poinsettia* cv. Brilliant Diamond were planted in media consisting of sphagnum peat and vermiculite (1:1) blended with the wetting agent Aqua-Gro 'G' (polyoxyethylene esters of cyclic acid (47%) + polyoxyethylene ethers of alkylated phenols (47%) + silicone antifoam emulsion (6%)) at 0, 0.23, 0.47, 0.94, 1.88 or 3.76 kg a.i./m³. The wetting agent at all rates had no effect on cutting establishment or root growth of *chrysanthemum* or *Pelargonium*. *Poinsettia* cuttings established well with all

concentrations of the wetting agent used, but plant height, plant width and root growth assessed 4 weeks after planting decreased linearly with wetting agent concentration. *Impatiens* cuttings were the most sensitive to the wetting agent. Although initial establishment of the cuttings was not affected, subsequent root and shoot growth was severely restricted with wetting agent rates above 0.94 kg/m³.

(1205)

Bing, A. (1983). Weed control on perennials. *Proceeding of the Annual Meeting of the Northeastern Weed Science Society*(37th): 352-356.

(1056)

Black, A. L. and J. K. Aase (1988). The use of perennial herbaceous barriers for water conservation and the protection of soils and crops. *Agriculture, Ecosystems and Environment* 22/23: 135 - 148.

A system of tall wheatgrass (*Agropyron elongatum*) barriers, which consisted of single or double rows of grass spaced at about 15-m intervals, protected the soil from wind erosion and conserved water for crop production. Windspeed at a height of 0.3 m above the soil surface was reduced over the intervals as a whole by about 45% by the grass barrier system, and potential wind erosion was reduced by 93.4% on an entire-year basis relative to open-field unprotected areas. The microclimate effects of the barriers relative to open-field environments include: (1) increased soil temperature in early spring; (2) decreased soil temperature in June due to greater crop canopy; (3) reduced soil drying rate of 0-100 mm soil depth following rainfall; and (4) increased winter wheat dry matter production, leaf area index and grain yields as a result of improved temperature-soil-water relations. The grass barrier system is an effective snow management tool which increased the probability of successful recropping with winter wheat (*Triticum aestivum*) from 55 to 78% with N fertilization over an 18-year period when 63 mm, or more, of the overwinter precipitation was stored in the soil. With N fertilization, winter wheat yields in the spring wheat-winter wheat-fallow rotation were _ 1360 kg/ha in 15 of 18 years or 83% of the time.

(1202)

Borochov, A., H. Spiegelstein, et al. (1997). Dormancy and storage of geophytes. *Proceedings of the seventh international symposium on flower bulbs*, Herzliya, Israel, 10 16 March 1996 No. 430:

405-409.

Dormancy is an integral part of the annual life cycle of most geophytes, characterizing perennial plants that exhibit seasonal growth. In addition, evergreen geophytes of tropical origin are forced into a dormancy period in horticultural practice. Unlike in tree buds and seeds, all types of dormancy (endodormancy, paradormancy and ecodormancy) occur in geophytes. The understanding of the mechanisms involved in the regulation of dormancy is very important since dormant geophytes are more resistant to environmental stresses, but only non-dormant planting material is expected to resume growth following planting. Studies of the hormonal regulation of dormancy are abundant. Clear roles for abscisic acid, as a dormancy inducing/maintaining hormone, and for gibberellins as dormancy breaking hormones have been revealed. Several reports support a similar role for ethylene. Although dormancy breaking involves modifications in overall cellular metabolism, no clear association between hormonal action and activated metabolism of geophytic organs has been described so far. Also, the molecular regulation of geophyte dormancy is very poorly understood. Results from work with *Liatris spicata* and *Caladium Xhortulanum* tubers are presented and discussed.

(1238)

Bowman, D. C. and J. L. Paul (1992). Foliar absorption in urea, ammonium, and nitrate by perennial ryegrass turf. *Journal of the American Society for Horticultural Science* 117(1): 75-79. The absorption and assimilation of ^{15}N -labelled urea, $(\text{NH}_4)_2\text{SO}_4$ and KNO_3 applied to the foliage of *Lolium perenne* cv. Manhattan II turf were examined under a controlled environment. Each source of N was dissolved in deionized water to a final concentration of 25 g N/litre and sprayed at a rate of 5 g/m². Absorption of the fertilizer-N over 48 h, as measured by ^{15}N analysis of tissue digests, amounted to 35%, 39% and 40% for urea, $(\text{NH}_4)_2\text{SO}_4$ and KNO_3 , respectively. Absorption was also estimated by a washing procedure that measured the urea remaining on the foliage and by the increase in total N in the ryegrass tissue. There were no significant differences between the 3 methods for determining the absorption of $(\text{NH}_4)_2\text{SO}_4$ and KNO_3 . The washing methods, however, significantly overestimated absorption of urea. Partitioning of the absorbed N between tissues was similar at 48 h for all 3 N sources, averaging 32% in new leaves, 52% in old leaves and shoot tissue, and 16% in the roots. Most of the

absorbed urea- and $\text{NH}_4\text{-N}$ was assimilated by 48 h, whereas only half of the $\text{NO}_3\text{-N}$ was reduced during that period.

(558)

Brand, M. H. (1999). Small divisions of ornamental grasses produce the best growth following direct potting. *HortScience* 34(6): 1126-1128.

Potting of bare-root spring divisions is a simplified approach to ornamental grass production. Large and small divisions of eight common ornamental grasses were directly potted into 7-L nursery containers and grown outdoors for 20 weeks to determine an appropriate division size for each grass. Response to division size was dependent on the grass species. Large divisions of *Calamagrostis xacutiflora* 'Karl Foerster' (Schröd.) produced twice as many inflorescences as small divisions. At harvest, large divisions of *Miscanthus oligostachyus* 'Purpurascens' (Stapf.) had twice as many inflorescences and 1.5 times as many tillers as small divisions. However, new tiller production in large divisions was only 50% of that in small division plants. Large divisions of *Miscanthus sinensis* (Anderss.) cultivars produced more tillers and greater fresh and dry weights than did small divisions, but again, the differences were not proportional to the size difference between the initial divisions. Large divisions of *Panicum virgatum* (L.) produced 50 more tillers per plant than did small divisions, but plant weight, size, and number of inflorescences were not affected by division size. Plants from large divisions of *Pennisetum alopecuroides* (L.) Spreng. were 7 cm shorter than small divisions and produced 24% more inflorescences and 27% more tillers, but appeared nutrient and/or water stressed. For most grasses, smaller division size is recommended for direct spring potting.

(1167)

Brunet, J. and C. G. Eckert (1998). Effects of floral morphology and display on outcrossing in blue columbine, *Aquilegia caerulea* (Ranunculaceae). *Functional Ecology* 12(4): 596-606. The effect of variation in floral morphology and display on the level of outcrossing was investigated in 1996 in a Rocky Mountain (Colorado) population of the self-compatible, protandrous, perennial herb *Aquilegia caerulea*. ANOVA revealed substantial variation among 36 plants in floral traits, including herkogamy, protandry, pollen production, flower size, the daily number of flowers in male phase and autofertility (seed production in the absence of pollinators). Whether

this floral variation affected the outcrossing rates of individual plants was assessed using both a categorical analysis, in which outcrossing rates were estimated separately for groups of plants that differed with respect to floral features, and a correlation analysis involving outcrossing rates estimated for individual plants from large progeny arrays ($n = 40$). Both analyses indicated significant positive correlations between the outcrossing rate and herkogamy ($r = 0.71$) and protandry ($r = 0.54$), negative correlations with the number of flowers in male phase during each day of female phase ($r = -0.42$) and autofertility ($r = -0.36$), but no correlation with flower size or pollen production. Partial correlation indicated that both herkogamy and dichogamy, although weakly intercorrelated, were positively correlated with the outcrossing rate and that these effects were only partly mediated by their negative correlation with autofertility. The extent to which floral features and outcrossing rate covaried across the flowering sequence within plants was also examined in this study. As expected for a plant with strong protandry and sequential blooming, the number of flowers in male phase decreased strongly with flowering sequence position. However, categorical analysis did not support the prediction that the first flowers to open on an inflorescence outcrossed at a lower rate than later-opening flowers. These results suggest that self-fertilization in *A. caerulea* is the result of all 3 major modes: autonomous and facilitated autogamy as well as geitonogamy. Although the geitonogamous component of selfing cannot be selected for directly, autogamy may be selected if it provides reproductive assurance.

(1207)

Bucsbau, H., Y. Kleifeld, et al. (1985). Selective weed control in geranium. *Phytoparasitica* 13(3-4): 246-247.

Perennial weed infestation in geranium [*Pelargonium graveolens*] fields was reduced during field preparation by cultivation, early irrigation to obtain germination of rhizomes and bulbs of perennial weeds, and treatment with systemic herbicides such as 2,4-D and glyphosate 2 weeks before transplanting cuttings. On medium-heavy soils, autumn planting in soil treated with oxadiazon enabled good plant establishment and residual herbicide effects prevented the emergence of annual weeds during the winter. Selective control was obtained with neburon + surfactant on foliage of young plants. Neburon + propyzamide controlled winter grasses while simazine applied at low rates in early winter controlled *Conyza* spp. although causing chlorosis and stunting when

applied to regrowth in the spring. Rooted cuttings were resistant to foliar-applied dinoseb acetate. In field trials in 1983, pendimethalin, neburon + pendimethalin and neburon + oryzalin provided effective weed control without damage when applied in late winter and activated by rain.

(1141)

Bugbee, G. J. (1994). Growth of rudbeckia and leaching of nitrates in potting media amended with composted coffee processing residue, municipal solid waste and sewage sludge. *Compost Science and Utilization* 2(1): 72-79.

Composts made from coffee processing residue (CFPR), source-separated municipal solid waste (MSW), sewage sludge + wood chips (SSWC), and sewage sludge + wood ash + wood chips + leaf compost (SSACL) were investigated as replacements for the [sphagnum] peat, perlite and sand in a conventional 5:3:2 (by volume) potting medium. Plants of the perennial *Rudbeckia hirta* cv. Goldilocks were container-grown in media composed of 0 (control), 10, 25, 50, 80 or 100% (by volume) of each compost. A standard slow-release NPK fertilizer was incorporated in all media. Leachate from media containing 0, 25, 50 or 100% compost was analysed for $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N} + \text{NH}_4\text{-N}$ to determine whether a compost would increase the potential for potting media to be sources of nitrate pollution in surface and ground water. Plants were also grown with or without 2 midseason applications of liquid fertilizer (containing 400 p.p.m. N, 176 p.p.m. P and 332 p.p.m. K) to determine the effects on growth and on N leaching. Differences in plant growth between control and compost-amended media were slight and statistically significant reductions in growth were observed only in media containing 80 or 100% CFPR or 80% SSACL. No compost induced a significant increase in growth. Leaching of N was greater from media composed of 100% CFPR, SSWC or SSACL than from the control medium. Less N was leached from media containing 25, 50 or 100% MSW than from the control. The use of a liquid fertilizer did not significantly affect plant growth or the amount of N found in the leachate from any medium.

(1138)

Byers, R. D. (1999). Reaching out: a university botanical garden builds long-distance relationships. *HortTechnology* 9(4): 573-576. Botanical gardens continually seek new ways to improve their education programs and increase their audiences. In the case of most university gardens, the larger academic community presents

many opportunities. However, what does a university garden do when separated by several hours travel from the campus served? Garvan Woodland Gardens and the University of Arkansas (UA) have developed several ways to address this challenge. A summer school session and Elderhostel program work together to benefit both partners in this alliance. This article discusses these efforts according to their structure, costs, and educational benefits.

(1116)

Calkins, J. B., B. T. Swanson, et al. (1996). Weed control strategies for field grown herbaceous perennials. *Journal of Environmental Horticulture* 14(4): 221-227.

Fourteen herbicides or herbicide combinations, wood chip mulch, chipped rubber tyre mulch and newspaper mulch were evaluated for weed control efficacy and phytotoxicity using 12 ornamental herbaceous perennials (*Hosta lancifolia*, *Liatris spicata*, *Hemerocallis* cultivars *After Dark* and *Young Love*, *Iris sibirica*, *Iris* cultivars *Gypsy Eyes* and *Singing Angel*, *Lilium* cv. *Willowwood*, *Paeonia* cv. *Felix Crouse*, *Phlox maculata* cv. *Omega*, *Schizachyrium scoparium* and *Festuca ovina*) under field growing conditions at St. Paul, Minnesota. The effect of herbicide application time was monitored by applying herbicides to dormant and actively growing plants. Herbicide and mulch treatments were compared with weeded and non-weeded controls. Herbicide phytotoxicity was dependent on age and species of herbaceous perennial and time of herbicide application. Herbicide injury was generally greater for young plants than for established plants and phytotoxicity was usually reduced when herbicides were applied to dormant rather than actively growing plants. Injury was sometimes greater when herbicides were applied in early spring than when applications were made after complete emergence. Injury to young shoots that had emerged prior to the earliest possible time that herbicides could be applied in the spring was probably involved. Applying herbicides in the autumn may avoid such injury. Mulching field grown perennials with wood chips provided the most effective weed control and often the best quality plants. With the exceptions of *Hemerocallis* cv. *After Dark* and *P. maculata* cv. *Omega*, the herbaceous perennials evaluated were tolerant of most of the herbicides applied. Several herbicides, including *Balan 2.5G* [benfluralin] at 3.36 kg a.i./ha, *Snapshot 80DF* (isoxaben + oryzalin) at 4.48 kg a.i./ha, and *Stomp 60WDG* (pendimethalin) at 4.48 kg a.i./ha, demonstrated potential for weed control in herbaceous perennial

production systems and landscape plantings. Goal 1.6EC (oxyfluorfen) at 1.68 kg a.i./ha and *Ronstar 50WP* (oxadiazon) at 3.92 kg a.i./ha were often phytotoxic when applied to herbaceous perennials.

(1240)

Cameron, R. W. F. and G. R. Dixon (1997). Air temperature, humidity and rooting volume affecting freezing injury to *Rhododendron* and other perennials. *Journal of Horticultural Science* 72(4): 553-562.

Intensive husbandry of woody plants grown in containers may increase the opportunities for cold-induced damage especially where rooting volumes are restricted. Experiments were conducted on *Acer palmatum* cv. *Aureum*, *Ceanothus* cv. *Autumnal Blue*, *Euphorbia griffithii* cv. *Fireglow*, *Magnolia soulangiana* and *Rhododendron* cv. *Hatsugiri* to study the range of damaging temperatures, their rates of change, the effects of relative humidity on foliar damage and the interaction between rooting volume and the duration of low temperatures on plant death. Damage was assessed visually and in terms of increasing ion leakage from the tissues. Exposing *Rhododendron* leaves to 2°C for 24 h prior to freezing at -6°C for 5 h was less damaging than the same treatment after exposure to 25 or 16°C. Damage resulting from treatments at -8 and -10°C was similar for leaves previously exposed to 25, 16 or 2°C. The extent of injury was also influenced by the environment during freezing. During short periods of freezing temperatures below -4°C, tissues submerged in water, and then frozen, generally showed less injury than those surrounded by air. At lower subzero temperatures and with longer periods of exposure, however, the greatest injury occurred in tissues placed in water. When exposed to -6°C, submerged leaves were damaged after 5 h whereas leaves placed in air withstood freezing for up to 7 h. Similar results were obtained with studies of the moisture contents of leaves and the ambient humidity during freezing. At -4°C leaves saturated with moisture suffered significantly less damage than those placed in dry atmospheres. Extending the drying period from 1 to 24 h prior to exposure to freezing, however, reduced tissue injury especially at the lowest temperatures. Results obtained by freezing plants grown in containers of several sizes for *Acer*, *Ceanothus*, *Euphorbia* and *Magnolia* were pooled. These confirmed that survival increased significantly in larger containers as air temperature was reduced over time for all species, with the possible exception of *Acer*.

(1237)

Chapman, D. S. and R. M. Auge (1994). Physiological mechanisms of drought resistance in four native ornamental perennials. *Journal of the American Society for Horticultural Science* 119(2): 299-306.

The drought resistance of 4 potted ornamental perennials native to the USA (*Echinacea purpurea*, *Rudbeckia fulgida* var. *sullivantii*, *Monarda didyma* and *Helianthus angustifolius*) was characterized in greenhouse experiments. Stomatal conductance of leaves of drying plants, lethal water potential and relative water content, and leaf osmotic adjustment during the lethal drying period were measured. *E. purpurea* had low leaf water potential (PSIL) and relative water content (RWC) at stomatal closure and low lethal PSIL and RWC, indicating high dehydration tolerance, relative to the other 3 species. *R. fulgida* var. *sullivantii* had a similar low PSIL at stomatal closure and low lethal PSIL and displayed relatively large osmotic adjustment. *M. didyma* had the highest PSIL and RWC at stomatal closure and an intermediate lethal PSIL, yet displayed a relatively large osmotic adjustment. *H. angustifolius* became desiccated more rapidly than the other species, despite having a high PSIL at stomatal closure; it had a high lethal PSIL and displayed very little osmotic adjustment, indicating relatively low dehydration tolerance. Despite differences in stomatal sensitivity, dehydration tolerance, and osmotic adjustment, all 4 perennials fall predominantly in the drought-avoidance category, relative to many plant species.

(1244)

Cohen, L. (1993). Perennials for sale! II. *Am Nurseryman* 177(7): 30-39.

(1243)

Cohen, L. (1993). Perennials for sale! I. *Am Nurseryman* 177(6): 62 - 67, 70 - 71.

(1245)

Cohen, L. (1993). Perennials for sale! III. *Am Nurseryman* 177(8): 62-67.

(557)

Conlon, H. P. (1999). *Dianthus gratianopolitanus* 'Firewitch'. *American Nurseryman* (December 1): 102.

(1058)

Corell, T. and A. Bing (1980). Preemergence weed control in ornamental perennial crops. *Proceedings of the Northeastern Weed Science Society*, 1980

34: 334-339.

A wide variety of container grown perennial plants were kept reasonably free from weeds and made normal growth when treated in the autumn or spring with simazine at 0.5 lb + oxadiazon 2 lb/acre. Oxadiazon at 2-8 lb/acre was safe to the crops. Treatment after potting in the autumn combined with re-treatment in spring controlled weeds for the entire production cycle and reduced [hand?] weeding costs by about 85%

(1230)

Cox, R. A. and J. E. Klett (1984). Evaluation of some indigenous Western plants for xeric landscapes. *HortScience* 19(6): 856-858. Forty-five indigenous plants, mostly herbaceous perennials, were transplanted into a field plot and evaluated for water requirements and landscape value. The majority of species showed no significant differences in growth between irrigated and non-irrigated treatments. Several species are suggested for use as ornamentals in dryland or low-maintenance situations, including *Artemisia frigida*, *A. cana*, *Chrysothamnus nauseosus*, *Dianthus anatolicus*, *Eriogonum umbellatum*, *Gaillardia aristata* and *Mirabilis multiflora*.

(1183)

Crawford, D. J., J. D. Palmer, et al. (1990). Chloroplast DNA restriction site variation and the phylogeny of *Coreopsis* section *Coreopsis* (Asteraceae). *American Journal of Botany* 77(4): 552-558. A total of 14 restriction site mutations and 1 length mutation were detected in 9 species of the section. Cladistic analysis of the tDNA data produced a phylogeny that differed in several respects from previous hypotheses. ctDNA mutations divided the section into 2 groups, with the 2 perennial species *C. auriculata* and *C. pubescens* lacking any derived restriction site changes. The other 7 species were united by 5 synapomorphic restriction site mutations and the length mutation. These 7 species fell into 3 unresolved clades consisting of (1) the remaining 3 perennial species, *C. grandiflora*, *C. intermedia* and *C. lanceolata*; (2) 3 annual species, *C. basalis*, *C. nuecensoides* and *C. nuecensis* and (3) the remaining annual, *C. wrightii*. The ctDNA data suggest that although the perennial habit is primitive within the section, the annual species of section *Coreopsis* probably did not originate from an extant perennial species. The estimated proportion of nucleotide differences per site (given as 100p) for the ctDNAs of species in the section ranges from 0 to 0.20, which is comparable to or lower than values reported for

other congeneric species. The low level of ctDNA divergence is concordant with other data, including cross compatibility, interfertility and allozymes, in suggesting that species of the section are not highly divergent genetically.

(196)

Creamer, N. G., M. A. Bennett, et al. (1997). Evaluation of cover crop mixtures for use in vegetable production systems. *HortScience* 32(5): 866-870.

Planting polyculture mixtures of cover crops can optimize the benefits of their use. Thirteen polyculture mixtures of cover crops were evaluated in Columbus and Fremont, Ohio, to find a species mix that would establish quickly for erosion control, overwinter in Ohio, contribute sufficient N and have a C : N ratio between 20:1 and 30:1 to optimize N availability for subsequent crops, be killable by mechanical methods, and have high weed control potential. All of the mixtures in Columbus had achieved 30% ground cover 1 month after planting, but only four of the mixtures achieved this in Fremont due to poor conditions at planting. Above-ground biomass (AGB) accumulation in the mixtures ranged from 3631 to 13,642 kg.ha⁻¹ in Columbus, and 449 to 12,478 kg.ha⁻¹ in Fremont. Nitrogen in the AGB ranged from 74 to 269 kg.ha⁻¹ in Columbus, and 10 to 170 kg.ha⁻¹ in Fremont. Weed cover in the cover crop plots ranged from 1% to 91% eight weeks after cover crop kill in Columbus, and 12% to 90% seven weeks after cover crop kill in Fremont. Because one or more species in each screened mixture was determined not to be suitable, none of the mixtures was optimum. However, information gained about performance of individual species within the mixtures is also useful. 'Nitro' alfalfa (*Medicago sativa* L.), ladino clover (*Trifolium repense* L.), subterranean clover (*Trifolium subterraneum* L.), Austrian winter peas [*Pisum sativum* ssp. *Arvense* (L.) Poir], and annual ryegrass (*Lolium multiflorum* Lam.) did not overwinter dependably in Ohio. Tall fescue (*Festuca arundinacea* L.), perennial ryegrass (*Lolium perenne* L.), and orchardgrass (*Dactylis glomerata* L.) did not compete well with

(1152)

Criddle, R. S., M. S. Hopkin, et al. (1994). Plant distribution and the temperature coefficient of metabolism. *Plant, Cell and Environment* 17(3): 233-243.

The relationship between metabolic activity and native environment in the temperature range between the limits of stability was examined using

a range of species including grasses and forage plants, trees, weeds, ornamentals and berry crops. Metabolic heat rate was measured as a function of temperature by scanning calorimetry for barley (a high latitude plant) and tomatoes (low latitude) to demonstrate typical temperature response curves of plants adapted to different environments. Temperature relationships (Arrhenius plots) were also determined for plants of the same or closely related species in different environments. Low-latitude and low-altitude woody perennials had larger Arrhenius temperature coefficients for metabolism than those for congeneric high-latitude and high-altitude plants. The Arrhenius temperature coefficient did not rapidly adapt to new environments. A function was developed that related Arrhenius temperature coefficient to latitude and altitude for accessions of 3 woody perennial species complexes of plants collected from a wide geographic range and grown at the same site. Temperature coefficients varied with growth stage and season, and plants which experienced broader temperature ranges in their native habitats had smaller temperature coefficients. No similar relationship was found for annuals and herbaceous perennials. Temperature coefficients were high during early spring growth and lower later in the season. The shift in temperature coefficients occurred earlier in the season for southern and low-altitude plants and progressively later for plants from further north or higher altitude. The changes in Arrhenius temperature coefficients were due mainly to increases in plant metabolic rates at lower temperatures while little change occurred in rates at higher temperatures. It is concluded that altering the temperature dependence of the control of metabolic rate is an important mechanism for responding to climatic change.

(1084)

Cripps, R. W. and H. K. Bates (1993). Effect of cover crops on soil erosion in nursery aisles. *Journal of Environmental Horticulture* 11(1): 5-8. The effectiveness of soil erosion control of various vegetative aisle covers was evaluated using Universal Soil Loss Equation (USLE) type plots. *Lespedeza cuneata* cv. Appalaw, crimson clover (*Trifolium incarnatum*) and perennial ryegrass (*Lolium perenne*) aisle treatments and a clean till plot were established on a 5% slope Typic Paleudult soil. Previously established trees of cv. Indian Magic crabapple and silver maple (*Acer saccharinum*) were grown parallel to the slope in the centre of each plot. Runoff from the clean-till aisle resulted in the greatest sediment

concentration, runoff volume and sediment runoff. There was little difference between the runoff from crimson clover and perennial ryegrass. The lespedeza aisle cover had the highest runoff volume of any vegetative aisle cover. However, runoff sediment concentration and sediment runoff were least from lespedeza-covered aisles.

(1169)

Cruzan, M. B. and M. L. Arnold (1994). Ecological and genetic associations in an Iris hybrid zone. *Evolution* 47(5): 1432-1445. Chloroplast DNA (ctDNA) markers and 12 (nuclear) random amplified polymorphic DNA (RAPD) markers were used to examine the distribution of genetic variation among individuals and the genetic and ecological associations in a hybrid iris population. Plants in the population occurred at various distances from the edge of a Louisiana bayou in a relatively undisturbed mixed hardwood forest and in an adjacent pasture dominated by herbaceous perennials with interspersed oak and cypress trees. The majority of plants sampled possessed combinations of markers from the different Iris species. Genetic markers diagnostic for *I. fulva* and *I. brevicaulis* occurred at high frequencies, whereas markers diagnostic for *I. hexagona* were infrequent. For the majority of the nuclear markers, significant levels of cytonuclear disequilibria existed because of intraspecific associations among the markers in both the pasture and the forest. The distribution of nuclear markers among individuals was bimodal; intermediate genotypes were absent and the majority of RAPD markers were associated with their intraspecific ctDNA haplotypes. Strong intraspecific associations existed among RAPD markers in the forest, but associations tended to be weaker in the pasture. Ecological correlations were detected for all but one of the *I. fulva* and *I. brevicaulis* RAPD markers. The ecological associations of hybrids similar to *I. brevicaulis* resembled associations of *I. brevicaulis* parental genotypes, suggesting that these hybrid genotypes may be relatively fit in the same habitats. The hybrids similar to *I. fulva*, however, were distributed in habitats that were unique relative to the parental species. The patterns of genetic and environmental associations along with other available data suggest that (1) only advanced generation hybrids were present in the population; (2) formation of F1 hybrids among Louisiana irises is rare, leading to sporadic formation of hybrid populations; and (3) selection and assortative mating have contributed to the formation of hybrid genotypes that tend to be similar to parental

genotypes. The patterns of ecological and genetic associations detected in this population suggest that assortative mating and environmental and viability selection are important in the structuring and maintenance of this hybrid zone.

(561)

Dahiya, S. S., S. Narender, et al. (1998). Effect of nitrogen and phosphorus on growth, flowering and yield of marigold (*Tagetes erecta* L.). *Environment and Ecology* 16(4): 855-857.

Marigold is an important cut flower crop in India. Greenhouse studies were conducted during 1996-97 to assess the effect of N (0, 80, 160 and 240 ppm) and P (0, 40, 80 and 120 ppm) on growth, flowering and yield of potted African marigolds grown in a sandy loam soil. The number of days to 50% flowering were significantly reduced with increasing N and P rates. The number of flowers/plant, plant height, and number of branches/plant were increased up to 240 ppm N, whereas plant spread decreased beyond 180 ppm N. Beyond 180 ppm N, no beneficial effect was observed on flower yield. Increasing P rates significantly improved the growth parameters and yield of marigold.

(1117)

Datta, S. K. and P. H. Kitto (1991). Role of mutation breeding in floriculture.

In Indian mutation breeding work, stem cuttings of single and double bracted Bougainvillea, Hibiscus, Lantana depressa and perennial Portulaca, rooted cuttings of garden Chrysanthemum, budwood of the rose and bulbs of single and double type Polianthes tuberosa were treated with different doses of gamma rays. The radiosensitivity of the material was determined on the basis of cytological and morphological indices, and somatic mutations in flower colour/shape and foliage were induced and detected as chimaeras in the M1V1 and later vegetative generations. The mutation frequency and spectrum varied with the cultivar and gamma ray dose. In all, 60 induced mutants were bred for commercial production (2 of Bougainvillea, 37 of Chrysanthemum, 1 of Hibiscus, 2 of L. depressa, 10 of rose, 6 of perennial Portulaca and 2 of tuberosa).

(1140)

Davison, J. G., A. G. Jones, et al. (1982). Weed control in fruit and other perennial crops. Weed competition and its effect on crop quality including harvest delays and weeds as hosts of pests and diseases are reviewed. Control of weeds by cultivation, mulching and herbicides are

outlined and the development of herbicide use described. Factors affecting herbicide effectiveness including amount of weed growth, undisturbed soil, dosage, soil type, weather and soil m.c. and method and timing of application are discussed. Crop tolerance, impact of herbicides on crop production and weed control programmes are evaluated.

Alternative Abstract: Aspects considered include the type of weeds of perennial crops, reasons for controlling weeds, methods of control (cultivation, mulching, chemical), the development of herbicide use, factors influencing the effectiveness of herbicides and affecting the tolerance of crops, the impact of herbicides on crop production and weed control programmes. Particular problems or special situations are considered including pre-planting treatments, newly-planted crops, grass swards, the control of unwanted crop vegetation, protected crops, container-grown plants and herbicide residues.

(372)

Derr, J. F. (1994). Weed control in container-grown herbaceous perennials. *HortScience* 29(2): 95-97.

Tolerance of transplanted black-eyed Susan (*Rudbeckia hirta* var. *pulcherrima* (Farw.), lanceleaf coreopsis (*Coreopsis lanceolata* L.), shasta daisy (*Chrysanthemum X superbum* Bergmans ex. J. Ingram), purple coneflower [*Echinacea purpurea* (L.) Moench], and blanket flower (*Gaillardia aristata* Pursh) to preemergence herbicides was evaluated in container trials. Herbicides were applied at the maximum use rate and twice the maximum use rate. Dithiopyr, pendimethalin, and proflumicarb provided excellent control of spotted spurge (*Euphorbia maculata* L.) and yellow woodsorrel (*Oxalis stricta* L.) with little injury to the five herbaceous perennials. DCPA, oxadiazon, and metolachlor were tolerated by all treated species, but these chemicals provided lower control of one or both weed species. Oryzalin, isoxaben + trifluralin, and napropamide caused unacceptable injury and shoot fresh-weight reductions in some of the perennials at one or both application rates.

(1074)

Desai, B. M. (1974). New cultivars of perennial *Portulaca* through gamma radiation. *Indian Horticulture* 19(2): 19, 23.

Brief descriptions are given of the flower characteristics of 5 *P. grandiflora* mutants.

(1153)

Eckert, C. G. and S. C. H. Barrett (1994). Tristyly, self-compatibility and floral variation in *Decodon verticillatus* (Lythraceae). *Biological Journal of the Linnean Society* 53(1): 1-30.

Heterostyly typically involves reciprocal polymorphism in stamen and style lengths, physiological self- and intramorph-incompatibility, and a set of associated polymorphisms of pollen and stigma characters. This study examined floral morphology and compatibility relationships in the monotypic, herbaceous perennial *D. verticillatus* occurring in wetland habitats throughout eastern-central North America. There have been conflicting reports on the occurrence of tristyly in the species, probably because of frequent loss of style morphs from populations in parts of the species' range. Floral morphology was examined in 20 flowers collected from each of 3 widely separated (eastern Ontario, Florida and Michigan) trimorphic and 2 dimorphic (eastern Ontario) natural populations. Detailed floral measurements revealed discrete trimorphism in style length and anther positioning in three populations. Data from the dimorphic populations showed similar patterns of floral polymorphism, although the mid-styled morph was missing. In one dimorphic population there was evidence for modification in the length of mid-level stamens. Measurements in three populations indicated pronounced floral variability, including high frequencies of modified phenotypes with reduced stigma-anther separation. Pollen size was only weakly differentiated among anther levels and there were no differences in pollen production among anther levels or morphs. In contrast, stigma size and papilla length showed a strong negative correlation with style length; a pattern opposite to most heterostylous species. Experimental crosses performed under glasshouse conditions on plants from one trimorphic and one dimorphic population from eastern Ontario showed a high degree of self- and intramorph-compatibility. Analysis of floral morphology showed that *D. verticillatus* was not unusual in terms of the precision and reciprocity of organ positioning compared with 13 other tristylous species.

(1184)

Eckert, C. G. and A. Schaefer (1998). Does self-pollination provide reproductive assurance in *Aquilegia canadensis* (Ranunculaceae)? *American Journal of Botany* 85(7): 919-924.

The ability to produce seeds when pollinators or potential mates are scarce is thought to be one of the main advantages of self-fertilization in

flowering plants. However, whether autonomous selfing increases seed set in natural populations has seldom been tested, and even fewer studies have evaluated the advantage of selfing across a gradient of pollen availability. This study examines the fertility consequences of autonomous selfing in *Aquilegia canadensis* (Ranunculaceae), a short-lived, spring-flowering perennial typically found in small, patchy populations on rock outcrops. A pollinator exclusion experiment was used to confirm reports that *A. canadensis* has a well-developed capacity for autonomous selfing resulting from incomplete protogyny and close proximity of stigmas and anthers during dehiscence. Flowers excluded from pollinators set 87% as many seeds per carpel (mean = 7.1 ± 1.4 seeds) as hand-pollinated flowers (8.1 ± 1.3 seeds), and seed production in unpollinated flowers correlated negatively with the distance between stigmas and anthers ($r = -0.46$). Autonomous selfing could be potentially valuable in providing reproductive assurance because only 2.7 ± 0.5 pollen grains were deposited on each stigma before anther dehiscence, compared to 134.1 ± 17.9 pollen grains by the end of anther dehiscence. However, prevention of autonomous selfing by anther removal before dehiscence did not decrease seed set, even for plants at low plant densities where outcross pollen may have been in short supply. Emasculated flowers set as many seeds per carpel (9.3 ± 0.9) as intact flowers (8.4 ± 1.1), indicating that sufficient cross pollen is deposited for full seed set. These results do not support the hypothesis that autonomous selfing by *A. canadensis* has been selected because it provides reproductive assurance.

(626)

Elkies, T., M. Haikel, et al. (1987). Application of growth regulators for the adaptation of some perennial plants to container production. *Gartenbauwissenschaft* 52(5): 210-213. *Bougainvillea glabra*, *Lantana camara* and *Hydrangea macrophylla* plants sprayed with 1000 and 2000 p.p.m. GA3 produced longer shoots, resulting in taller plants, and a reduction in the number of branches. Chlormequat (CCC) at 2000 and 4000 p.p.m. following GA3 applications prevented excessive plant height, resulted in growth which was in proportion to the size of the container and improved quality. *Hydrangea* treated with GA3 or with CCC alone showed phytotoxicity symptoms and chlorotic growth. The application of CCC or ancymidol (2000 or 4000 p.p.m. each) increased branching but restricted the height of *Hibiscus rosa-sinensis*, *Fuchsia speciosa*

and *Euphorbia pulcherrima*. Ancymidol was more effective than CCC in reducing plant growth. Ancymidol and CCC reduced height and bract size of poinsettias, but had no effect on quality.

(1231)

Erusha, K. S., C. Fricker, et al. (1991). Effect of preemergence herbicide on wildflower establishment. *HortScience* 26(2): 209. In trials near Mead, Nebraska, and near Hubbard, Oregon, on a Sharpsburg silty clay loam and a Willamette sandy loam, respectively, 50 or 47 wildflower species (both annual and perennial), respectively, were sown on untreated plots (control) or on plots treated with 2.3 kg EPTC/ha and 0.6 kg trifluralin/ha and rotary-cultivated immediately after herbicide application. Plots were irrigated with 4 mm water/d for 6 weeks after sowing, then with 13 mm/week. Stand ratings for all species at both sites are tabulated. About 35% of species were adversely affected by herbicide application.

(612)

Fare, D. C., C. H. Gilliam, et al. (1996). Cyclic irrigation and media affect container leachate and ageratum growth. *Journal of Environmental Horticulture* 14(1): 17-21. Two experiments were conducted with container-grown *Ageratum houstonianum* cv. Blue Puffs to compare cyclic and continuous irrigations. In experiment 1, leachate volumes were reduced by about 54% with cyclic irrigation treatments (0.4 cm water) applied with either a 30-min or 2-h resting phase compared with continuous irrigation at the same rate. Total N leached was about 47% less with the cyclic treatments than with continuous irrigation. In experiment 2, container leachate volumes and N leached were higher from a pine bark:sand medium, while plants were smaller than from a pine bark:peat medium. Growth index and root distribution were similar with cyclic and continuous irrigation.

(1208)

Fay, A. M., M. B. McDonald, et al. (1993). Vigor testing of *Rudbeckia fulgida* seeds. *Seed Science and Technology* 21(2): 453-462. Accelerated aging and conductivity tests for seed vigour were conducted on *R. fulgida* seeds. The optimum regime for the accelerated aging test was aging for 24 h followed by germination at $30 \pm 1^\circ\text{C}$. Bulk conductivity readings, taken after soaking seeds in distilled water at 20°C for 24 h, distinguished vigour among 3 seed lots, supporting the results of the accelerated aging test. Field,

greenhouse and cold tests using field soil resulted in poor germination, indicating that these vigour tests were not suitable for *R. fulgida* seeds. However, tests conducted in soilless mixtures supported the results of the accelerated aging and conductivity tests. It is suggested that vigour test correlations should be compared with germination/emergence tests conducted in soilless media rather than in field soil. It is concluded that seed quality of *R. fulgida* and other herbaceous perennials could be evaluated using bulk conductivity and accelerated aging tests.

(656)

Fenwick, H. S. (1971). Perennial ornamental plants, how to tell if they are sick and what to do about it. Idaho Current Information Series(146): 1 - 4.

(657)

Fenwick, H. S. (1971). Diseases of perennial ornamental plants. Cooperative Extension Service, Oregon State University(Circular 780): 1 - 4.

(1235)

Fernandez, R. T., T. Whitwell, et al. (1999). Evaluating semiaquatic herbaceous perennials for use in herbicide phytoremediation. Journal of the American Society for Horticultural Science 124(5): 539-544.

Canna X generalis (canna), *Pontaderia* [*Pontederia*] *cordata* (pickerel weed) and *Iris* cv. *Charjoys Jan* were exposed to a 5-mg/litre suspension of isoxaben or oryzalin or a water control for 9 days. Growth and photosynthetic responses were monitored throughout treatment and for an additional 22 days after termination of treatment. By the end of the experiment plant height of pickerel weed was reduced by oryzalin. Isoxaben resulted in lower height and reduced leaf emergence for all 3 taxa by the end of the experiment. Leaf CO₂ assimilation (A) and transpiration (E) were lower for oryzalin-treated canna only 17 and 18 days after treatment, several days after treatment had been terminated. Leaf A and E were lower for oryzalin-treated pickerel weed and *Charjoys Jan iris* for most days after day 17. Isoxaben reduced A and E of all 3 plants for all days measured except day 6 for *Charjoys Jan iris*. Lower photosystem II efficiency (Fv/Fm) was found for isoxaben-treated canna from day 5 onward and days 7, 20 and 23 for pickerel weed and *Charjoys Jan iris*. Rapid reduction in A and Fv/Fm for all plants treated with isoxaben indicated a direct effect of isoxaben on photosynthesis. Reductions in growth and

photosynthetic parameters due to oryzalin were minimal for all plants indicating these plants would be useful in phytoremediation systems where oryzalin is present. However, growth and photosynthetic parameters were reduced substantially for all plants exposed to isoxaben indicating the taxa studied would not perform well in phytoremediation systems with this level of isoxaben exposure.

(1085)

Finnerty, T. and J. M. Zajicek (1992). Effects of seed priming on plug production of *Coreopsis lanceolata* and *Echinacea purpurea*. Journal of Environmental Horticulture 10(3): 129-132. Seeds of *C. lanceolata* and *E. purpurea* were primed in 50 mM potassium phosphate buffer (KH₂PO₄ + K₂HPO₄, pH 7.0) to determine whether improved plug production of these herbaceous perennials would result. Experiments were conducted at 2 locations: Texas A&M University (TAMU), College Station, and Buell's Inc., Cibola, Texas. Location had a significant effect on emergence, with both species having greater emergence percentages at Buell's Inc. than at TAMU. This effect is attributed mainly to watering systems and plug aeration. Priming significantly increased emergence of only *E. purpurea* grown at TAMU. Seedlings from seeds primed in 50 mM K salts for 9 days at 15°C had more than twice the emergence percentage (47%) of seedlings from nonprimed seeds (21%). Priming did have a significant effect on the root development of both species. *E. purpurea* seedlings from primed seeds had a 44 to 51% increase in total root area compared with nonprimed seeds. *C. lanceolata* seedlings from primed seeds had up to an 85% increase in root area compared with seedlings from nonprimed seeds. In plug systems, relatively well-developed root systems may result in positive growth response after transplanting.

(1166)

Fitter, A. H., R. Nichols, et al. (1988). Root system architecture in relation to life history and nutrient supply. Functional Ecology 2(3): 345-351. Extreme topologies for root systems can be viewed either as minimizing cost or maximizing efficiency of soil exploration. Plants of *Trifolium pratense*, lettuce, *Festuca ovina*, *F. rubra*, *F. nigrescens*, *F. pratensis* and 3 *Geranium* species were grown in a range of nutrient supply conditions to test this hypothesis. Topology was generally insensitive to changes in N and P supply but large differences between species were found. Slow-growing perennials had efficient herring-bone systems,

whereas annuals were at the opposite extreme which accords with earlier predictions. Lengths of external links were reduced by N and of internal links by P. There were large differences between species in mean link lengths. These data confirm the value of topological analyses in understanding the functional architecture of root systems.

(1112)

Flemer, W., III (1977). Choosing attractive ground covers to reduce maintenance costs. *American Nurseryman* 145(10): 7-8, 20...36.

Descriptions are given of some 25 perennial spp. suitable for ground cover, including *Cotoneaster*, *Hedera* and *Juniperus* spp., with details of their relative cold hardiness and normal height under cultivation.

(1121)

Francois, L. E. (1980). Salt injury to ornamental shrubs and ground covers. *Home and Garden Bulletin*, United States Department of Agriculture (No. 231): 10 pp.

Advice on symptoms of damage and means of reducing soil salinity, with lists of woody and herbaceous perennials that have shown high, good, moderate, poor or very poor tolerance of saline conditions in trials at the US Salinity Laboratory.

(373)

Frank, J. R. and J. A. King (1979). Metolachlor and Alachlor for Weed Control in Establishing Woody Nursery Stock. *Proceedings of the Annual Meeting of the Northeastern Weed Science Society* 33: 228-231.

A field experiment was conducted to test the effectiveness of metolachlor and alachlor alone or in combination with simazine for weed control in the establishment of four species of woody nursery stock. Metolachlor and alachlor alone gave short-term control of annual weeds. Combinations with simazine lengthened the period of effective weed control. Follow-up treatments of glyphosate and paraquat were applied to control the perennial weed population. Glyphosate was more effective than paraquat in controlling weeds over a 45-day evaluation period.

(408)

Frank, J. R. and J. A. Simon (1981). Glyphosate and paraquat effectiveness in woody nursery stock. *Weed Science* 29(4): 455-461.

Six species of 2- or 3- yr-old woody nursery stock were planted in the field in May 1976. Glyphosate at 2.2 or 4.5 kg/ha or paraquat at 0.6 or 1.1 kh/ha were applied one or two times as directed sprays in

1976 and one, two, or three times each season in 1977 and 1978. Three applications of glyphosate or paraquat were required to control weeds during the entire growing season. When late-season applications of glyphosate were made during 1977, residual weed control was observed during early 1978. When glyphosate was applied twice a year for 3 yr at 4.5 kg/ha, four of the previously dominant perennial weeds were controlled, including common dandelion, broadleaf dock, buckhorn plantain, and red sorrel. Three applications provided 100% control of seven of the eight remaining broadleaf perennials, including hedge bindweed and Canada thistle; six of seven species of broadleaf annuals, including *Pennsylvania smartweed* and *tumble pigweed*; and all of the remaining grass weeds. Crop size, crop quality, and marketability of the six ornamental species were not adversely affected by either herbicide. Two or three applications of glyphosate at 2.2 kg/ha or two treatments at 4.5 kg/ha increased plant size on *andorra junipers*. Three treatments of glyphosate at 2.2 kg/ha also increased the size of dwarf Japanese yews and two treatments at 4.5 kg/ha increases the size of boxleaf Japanese holly.

(1066)

Frett, J. (1993). Perennials with panache. *Am Nurseryman* 177(3): 25-29.

Nine plants for sunne or shady sites: *Solidago sphacelata* 'Golden Fleece', *Amsonia hybrectii*, *Asclepias tuberosa* 'Gay Butterflies', *Sedum* x 'Brilliant', *Tiarella cordifolia*, *Batisia alba* var. *alba*, *Chrysanthemum pacificum*, *Aruncus aethu*???? (dwarf goat's beard).

(1115)

Garber, M. P. and K. Bondari (1993). Trends in plant material requirements of landscape architects. *Journal of Environmental Horticulture* 11(3): 110-115.

Landscape architects influence the demand for plant material when specifying plants for landscape projects. A survey of landscape architects in Georgia in 1991 identified the value of plant material specified for 9 plant types: deciduous trees (trunk diameter > 3 inches), deciduous trees (trunk diameter _ 3 inches), evergreen trees, coniferous shrubs, broadleaf shrubs, perennials/ground covers, native herbaceous, bedding plants and turf. The largest category of plants in terms of economic value was landscape trees, representing approx. 50% of the total value for all firms. With the exception of turf, landscape architects expect to specify the same or

greater value of plant material over the next 5 years, a positive economic sign for the nursery industry. The frequency of plant substitution due to lack of availability was greatest for the 5 plant types generally produced as container nursery stock in Georgia (coniferous shrubs, broadleaf shrubs, perennials/ground covers, native herbaceous and bedding plants). The 2 factors identified by landscape architects as most likely to affect the type of plants specified over the next 5 years were water availability and the need for low-maintenance landscapes.

(1092)

Garber, M. P. and K. Bondari (1998). Characteristics of garden writers and their information sources. *Journal of Environmental Horticulture* 16(4): 207-211.

A national survey of members of the Garden Writers Association of America (GWAA) indicated that Garden Writers tend to distribute their gardening communications within their state of residence and to a lesser extent, nationally. The most widely used media by Garden Writers were newspapers, magazines and television. The three types of plant material information that generated greatest consumer response for Garden Writers were low maintenance plants, herbaceous perennials, and new plant varieties. The type of services or information that Garden Writers valued the most were new plant releases, current pest problems in their area, and a listing of local suppliers of new plant varieties. Garden Writers maintain home gardens (97.3%) and most evaluate new plant varieties (88.1%) in their garden.

(1091)

Garber, M. P. and K. Bondari (1999). Garden writers plan to write about. *Journal of Environmental Horticulture* 17(1): 39-43. The five categories of plants projected by members of the Garden Writers Association of America (GWAA) to have the greatest future demand were herbaceous perennials, native ferns and wildflowers, ornamental grasses, herbs, and ground covers. This survey noted that the two most important plant traits likely to affect future demand are multi-seasonal color/interest and pest resistance/tolerance. In preparation of gardening communications about plants, the most valued sources of information were personal growing experience, readily available information, and success stories from the local arboreta/botanical garden. The type of plant material information most valued by Garden Writers was regional suitability, landscape requirements, and flowering

habit.

(1146)

Garbutt, S. (1994). The up-and-coming diascia. *Garden London* 119(1): 18-21.

The development of a number of outstanding perennial *Diascia* hybrids by the grower H. Harrison, of Appleby in South Humberside, is described. Species involved in the breeding programme include *D. rigescens*, *S. integerrima*, *D. fetcaniensis*, *D. lilacina*, *D. stachyoides* and *D. vigilis*. The most hardy and drought-tolerant species appear to be *D. vigilis*, *D. fetcaniensis* and *D. integerrima*; several early hybrids have survived 6 or 7 winters without protection in various parts of the UK. Plants are being introduced to Australia; due to the generally warmer climate, hardiness need no longer be a prime objective of the breeding programme. Some cultivars are described and advice is given on cultivation.

(32)

Garner, J. M., G. J. Keever, et al. (1997).

Benzyladenine-induced offset formation in *Hosta* dependent on cultivar. *HortScience* 32(1): 91-93. A foliar spray of 0, 1250, 2500, or 3750 mg benzyladenine (BA)/L was applied to 10 *Hosta* Tratt. (*Funkia* K. Spreng; *Niobe* Salisb.) cultivars. Response to BA treatment was cultivar dependent, with BA promoting offset formation in half of the cultivars. Compared to the control, increase in offsets produced by cultivars treated with 3750 mg BA/L ranged from 116% in 'Francee' to 3500% in 'Francis Williams' at 30 days after treatment (DAT) and from 150% in 'Royal Standard' to 2250% in 'Francis Williams' at 60 DAT. Offset stage of development, as indicated by the number of unfurled leaves, was also cultivar- and BA-dependent. All cultivars treated with 3750 mg BA/L had an average of three or more unfurled leaves at 60 DAT, while among control plants, 40% of cultivars averaged fewer than three unfurled leaves. No phytotoxic symptoms were noted in any cultivar, and plant size was either increased or not affected by BA treatment.

(1010)

Garner, J. M., G. J. Keever, et al. (1998).

Sequential BA applications enhance offset formation in *Hosta*. *HortScience* 33(4): 707-709. A study conducted in 1995 and repeated in 1996 determined the effects of repeated benzyladenine (BA) applications and subsequent repeated removals on yields of offsets in *Hosta* stock plants. Cultivars Francee and Francis Williams received

0, 1, 2, 3 or 4 foliar applications of 3000 mg BA/litre. Plants receiving multiple applications were retreated at 30-day intervals following offset removal from all plants. A single BA application stimulated offset formation in both cultivars in both years, but repeated applications were necessary for a continued response following offset removal. Total offset yield increased linearly as the number of BA applications increased. At 120 days after the first treatment in 1995, Francee plants receiving 4 applications had produced an average of 22 offsets, Francis Williams plants produced 18 offsets, and control plants produced 9.8 and 0 offsets for the 2 cultivars, respectively. For 1996 the data were 31.2 offsets for Francee and 22.4 offsets for Francis Williams, with 6.8 and 2.6 offsets for controls of each cultivar, respectively. Offset stage of development, as indicated by leaf number, and growth index were not affected by BA treatment. No phytotoxicity was observed, and plant appearance was enhanced due to the outgrowth of BA-stimulated lateral buds.

(44)

Garner, J. M., G. J. Keever, et al. (1997). BA application promotes offset formation in Hosta cultivars. *Journal of Environmental Horticulture* 15(3): 119-122.

A foliar spray of 0, 1250, 2500, or 3750 ppm BA was applied to 10 hosta cultivars. BA application promoted offset formation in 8 cultivars at 30 days after treatment (DAT) and in all cultivars at 60 DAT. At 30 DAT, no offsets had formed in controls (0 ppm BA) of 'Halcyon' or 'Samuel Blue', but plants receiving 3750 ppm BA averaged 3.1 and 5.5 offsets, respectively. In the remaining cultivars at 30 DAT, maximum increases in offsets compared to controls ranged from 0.9 offset for 'Stiletto' to 6.2 offsets for 'Hyacinthina'. Untreated plants of 'Halcyon' formed no offsets by 60 DAT, whereas plants receiving 3750 ppm BA averaged 3.8 offsets. In the remaining cultivars at 50 DAT, maximum increases in offsets compared to controls ranged from 2.1 offsets for 'Great Expectations' to 7.6 offsets for 'Stiletto'. Offset stage of development, based on number of unfurled leaves, was more advanced in treated plants than in controls of two cultivars, less than that of controls in two cultivars, and similar to control in the remaining cultivars. No phytotoxic symptoms were noted for any cultivar, and plant size was either increased or not affected by BA treatment.

(82)

Gill, S., R. Balge, et al. (1997). A new closed loop system. *Am. Nurseryman* (October): 68-70, 72, 74,

76, 78-79.

Research in the Cellugro inground production system shows that it could be a useful method for growing woody plants and perennials while conserving and recycling water

(734)

Gilliam, C. H., G. J. Keever, et al. (1992).

Postemergence applied herbicides for use on ornamental grasses. *Journal of Environmental Horticulture* 10(3): 136-139.

Postemergence-applied, grass-active herbicides registered for use in the landscape were applied over-the-top of four ornamental grass species to evaluate tolerance in 1990 and 1991. All herbicides caused some injury to all grass species. Growth indices of dwarf fountain grass (*Pennisetum alopecuroides* L.K. Spreng. 'Hameln') and pampas grass (*Cortaderia selloana* Schult. & Schult. f. Asch & Graebn. 'Rosea') treated with the low rate of Poast (sethoxydim) was similar to that of the nontreated plants in both years. Acclaim (fenoxaprop-ethyl) caused less injury to purple maiden grass (*Miscanthus sinensis* Anderss. 'Purpurescens') and maiden grass (*M. sinensis* Anderss. 'Gracillimus') than Poast and Fusilade 2000 (fluazifop). Both Acclaim rates resulted in similar growth indices to that of nontreated plants. Flowering was reduced in three of the four grass species with all grass active herbicide treatments; the fourth species did not flower.

(625)

Glatstein, J. (1990). Dividing perennial grass. *Org Gard* 37(4): 32-33.

(1189)

Godt, M. J. W. and J. L. Hamrick (1993). Genetic diversity and population structure in *Tradescantia hirsuticaulis* (Commelinaceae). *American Journal of Botany* 80(8): 959-966.

Tradescantia hirsuticaulis, the hairy-stemmed spiderwort, is an insect-pollinated perennial plant species found primarily on rock outcrops in Georgia, South Carolina and Alabama. Although populations of *T. hirsuticaulis* are rare and scattered, local populations are frequently large. Levels of genetic variation were assessed for 13 populations representing the species' range in these 3 states. Despite the disjunct distribution of this habitat specialist and apparent lack of specialized seed and pollen dispersal mechanisms, exceptionally high levels of genetic variation are maintained within the species, with a moderate level of variation (18%) found among populations. Twenty-nine of the 33 isoenzyme loci resolved

(88%) were polymorphic within the species; the mean number of loci polymorphic within populations was 54%. The mean number of alleles per polymorphic locus was 3.24 across all populations and averaged 2.37 within populations. Genetic diversity was 0.21 for the species, whereas mean population genetic diversity was 0.16, both much higher than the average for other short-lived herbaceous perennials. Estimated levels of gene flow were moderate ($N_m = 0.95$), and a significant association between geographic distance and genetic distance between populations was found ($r = 0.68$; $P < 0.0001$). Habitat destruction is the major threat to this genetically diverse species. Since gene flow among its highly dispersed populations is limited, diminution or extinction of local populations could jeopardize the long-term evolutionary potential of this species.

(1188)

Godt, M. J. W. and J. L. Hamrick (1991). Genetic variation in *Lathyrus latifolius* (Leguminosae). *American Journal of Botany* 78(9): 1163-1171. *Lathyrus latifolius* is a perennial vine native to Europe. Naturalized populations of *L. latifolius* occur in fields and on roadsides over large areas of the USA. Widely cultivated as a garden flower, *L. latifolius* produces abundant racemes of showy flowers that are bumblebee-pollinated. The seeds are heavy, large and round, and exhibit no specialized means of dispersal. Allozyme diversity and population structure were determined for 32 populations, 30 from the southeastern USA and 2 from Oregon. Results from 21 allozyme loci indicate that genetic diversity is higher and population divergence is lower than expected based on the life history characteristics of the species. No association was found between genetic identity statistics and geographic distance between populations. Although the range in genetic diversity statistics among populations was unusually large, genetic drift did not appear to play a major role in structuring genetic variation. It was concluded that the level of genetic diversity maintained within populations, and the level of population divergence found, is strongly influenced by its status as a cultivated garden flower and its human-associated mode of gene flow via seed dispersal.

(659)

Goode, H. (1973). Variety and color in the herbaceous perennial border. [Landscaping]. *Garden Journal* 23(4): 110 - 115.

(1216)

Griesbach, R. J. (1989). Selection of a dwarf *Hemerocallis* through tissue culture. *HortScience* 24(6): 1027-1028.

A procedure was developed for inducing somaclonal variation in *Hemerocallis* tissue culture. The frequency of genetic variation, however, was very low. A novel dwarf clone that may have commercial potential as a perennial border plant or pot plant was selected and registered as Yellow Tinkerbell.

(1136)

Grzesik, M. (1989). Factors influencing the effectiveness of growth regulators in nursery production. *Acta Horticulturae* No. 251: 371-375. The influence of different growth regulators on the growth and shapes of 19 perennial species and 22 shrub species [not specified] was examined initially. The results showed plant growth to be dependent on plant species, and growth regulator type and concentration. Further experiments were carried out on *Weigela florida* cv. *Styriaca*, *Forsythia* cv. *Maluch*, *Chamaecyparis lawsoniana* cv. *Eltwoodi* and *Juniperus communis* cv. *Suecica*. The plants were treated with GA3, GA3+4+7 or paclobutrazol at various concentrations and times of application. GA3 application resulted in increased stem elongation, and reduced branching and growth of lateral shoots. The effect of GA3 was limited by time of application but not by concentration. Paclobutrazol treatment increased branching, improved plant colour and flowering, and, at low concentrations, did not reduce plant height. Hand pinching or spraying with paclobutrazol or Atrinal [dikegulac], before or after GA3 treatment, resulted in improved branching and development of lateral shoots whilst simultaneously increasing the length of all shoots. For young plants, two treatments with low concentrations of growth regulators were found to be more successful than one treatment at a higher concentration.

(1161)

Gurevitch, J. (1992). Sources of variation in leaf shape among two populations of *Achillea lanulosa*. *Genetics* 130(2): 385-394. *Achillea lanulosa* is a small tetraploid herbaceous perennial native to N. America and has been recognized as part of the *A. millefolium* species complex. It has complex, highly dissected leaves that vary in shape and size along an altitudinal gradient. Plants from a high and an intermediate altitude population in the Sierra Nevada range in California were clonally replicated and grown in a controlled environment under warm and cool

conditions under bright light. There were genetic differences among populations and among individuals within populations in leaf size and shape. Heritabilities for leaf size and shape characters were moderate. Leaves of the lower altitude population were larger and differed from the higher altitude plants in both coarse and fine shape. Plastic response to temperature of the growth environment paralleled the genetic differentiation between low and high altitude populations. There was no apparent trade-off between genetic control over morphology and the capacity for directional plastic response to the environment. Differences in leaf dissection and size at contrasting altitudes in this species are the result of both genetic divergence among populations and of acclimative responses to local environments.

(1175)

Halfdan Nielsen, B. (1996). Five new species of *Geranium* (Geraniaceae) from Ecuador. *Nordic Journal of Botany* 16(3): 267-275.

Geranium aequatoriale, *G. angelense*, *G. guamanense*, *G. holmnielsenii* (all herbaceous perennial) and *G. loxense* (sub-shrub) are formally described and illustrated from different localities in the high Andean paramo areas in Ecuador.

(1129)

Hamaker, C. K., B. E. Engle, et al. (1996). Using growth regulators to control height of herbaceous perennials. *GrowerTalks* 60(6): 46...53.

The effectiveness of ancymidol (as A-Rest), daminozide (as B-Nine), paclobutrazol (as Bonzi), chlormequat (as Cycocel) and uniconazole (as Sumagic) for controlling the height of 35 herbaceous species was determined over 3 years. Plant response varied among growth regulators. No single growth regulator effectively controlled the height of every species, although most species responded to at least one chemical. Daminozide and uniconazole were the most effective, controlling height in 23 and 24 species, respectively. Seven species responded in some degree to all growth regulators, while 4 of the taller species did not respond to any treatment. The results are tabulated.

(1134)

Hamaker, C. K., R. Heins, et al. (1996). Perennials: best long-day treatments for your varieties. *GrowerTalks* 60(8): 36...42.

Achillea filipendulina, *Asclepias tuberosa*, *Campanula carpatICA* cv. Blue Clips, *Coreopsis lanceolata* cv. Early Sunrise, *Leucanthemum*

Xsuperbum cv. Snow Lady and *Salvia superba* were grown in the greenhouse at a constant 68°F, after exposure to 41° for either 0 or 12 weeks. Plants were forced under a 9-h short day or one of 5 long-day lighting strategies for 12 weeks. The long-day treatments were a 7-h day extension, a 4-h night interruption, a 7-h night interruption, a 7-h predawn extension and 24-h continuous light. All long-day treatments were delivered by incandescent lamps that provided a minimum of 10 foot candles. All long-day treatments induced flowering, but some were more effective than others for some species. In general, a 7-h predawn treatment was less effective than other treatments for inducing flowering. Response to long-day treatment was also affected by cold treatment. Flowering in *Campanula carpatICA* was significantly delayed in plants that did not receive cold treatment. Results for the number of days to first flower and flowering percentage are tabulated for each species and each light treatment following cold treatment or no cold treatment. Based on the results, advice on forcing herbaceous perennials is given to growers.

(1227)

Hanche, A. M. and A. C. Cameron (1995).

Harvest date and storage quality of herbaceous perennials. *HortScience* 30(3): 573-576.

The effect of harvest dates between Sep. and Dec. on regrowth after storage of field-grown *Coreopsis grandiflora* cultivars Sunburst and Sunray, *Geum quellyon* cv. Mrs. Bradshaw, *Gypsophila paniculata* cv. Snowflake, *Iberis sempervirens* cv. Snowflake and *Dicentra spectabilis* crowns was determined. After 0-7 months of storage at 0°C, stored crowns were repotted and grown in a greenhouse. Plants from later harvests were of higher quality than those from earlier harvests, showing higher rates of survival after longer storage periods, less mould development in storage and stronger regrowth after storage. Late field harvest is recommended for optimum storage quality.

(792)

Hanninen, K. S. (1998). Effects of clovers as vegetative ground cover on the growth of red birch in nursery field production. *J hort sci biotech* 73(3): 393-398.

During 1992-95, clover species were evaluated as vegetative ground covers in nursery field production of micropropagated red birch (*Betula pubescens* f. *rubra*) in Finland. The clover species and cultivars were *Trifolium pratense* cv. Bjursele, *T. repens* cv. Jogeva, *T. repens* cv. Sonja, *T.*

hybridum cv. Frida, *T. incarnatum* cv. Opolska, *T. resupinatum* and *T. subterraneum*. One treatment was grass sod *Festuca rubra* cv. Ensylva, and the control was coverless ground kept weed free by hand hoeing. Stem diameter, stem height, leaf area and leaf size were all reduced in the perennial clover and grass plots. The annual clovers, *T. incarnatum*, *T. resupinatum* and *T. subterraneum* were noncompetitive with the trees. Because of its low growth habit, *T. subterraneum* appeared to be the most suitable of the tested clovers as a ground cover crop.

(1068)

Hanzawa, F., M. and S. Kalisz (1993). The relationship between age, size, and reproduction in *Trillium grandiflorum* (Liliaceae). *American Journal of Botany* 80(4): 405 - 410.
The relative importance of age and size as predictors of demographic parameters such as survivorship or reproductive status is generally unknown for herbaceous perennials, due primarily to the difficulty in estimating the age of herbaceous plants. We investigated the relationship between age, size, and reproductive status in *Trillium grandiflorum*, a rhizomatous perennial herb in which age can be estimated. We measured the leaf area and rhizome volume and estimated the age of plants in a study population that included reproductive and nonreproductive individuals. Reproductive plants were significantly older (hivin $X = 22.8$ years) than nonreproductive plants (hivin $X = 13.3$ years). Reproductive plants also had significantly larger total leaf areas and rhizome volumes. Total leaf area, rhizome volume, and age were positively correlated in both groups. Reproduction in this population occurred once plants reached a threshold leaf area or rhizome volume. Both measures of plant size, i.e., total leaf area and rhizome volume, were better predictors of plant reproductive status than was plant age.

(1145)

Hardy, G. (1986). Herbaceous plant production at Blooms of Bressingham, Ltd. Combined Proceedings / International Plant Propagators' Society 36: 314 - 319.

(1214)

Harkess, R. L. and R. E. Lyons (1994). *Rudbeckia hirta* L.: a versatile North American wildflower. *HortScience* 29(3): 134, 227.
Taxonomy, characteristics, cultivars and research history (particularly photoperiodic response and floral development) are discussed.

(1217)

Haynes, J. G., W. G. Pill, et al. (1997). Seed treatments improve the germination and seedling emergence of switchgrass (*Panicum virgatum* L.). *HortScience* 32(7): 1222-1226.
Switchgrass (*Panicum virgatum*) is a perennial, warm-season grass native to North America, and is recommended as a component of wildflower meadows. Seed treatments which could alleviate low seed vigour and seed dormancy of *P. virgatum* would enhance establishment of plug transplants or seedlings after direct sowing into the meadow. Heavy seeds (45.5 mg/50 seeds) of open-pollinated *P. virgatum* stored under cool and dry conditions (average 13°C, 30% RH) for 24 months had higher germination percentage (45%) than light seeds (26.0 mg/50 seeds, 7%). In factorial combination, the heavy seeds were subjected to acid scarification (8 M H₂SO₄ for 5 minutes), sodium hypochlorite treatment (5.25% NaOCl for 15 min) and moist chilling (prechilling in 0.2% KNO₃ for 14 days). Acid scarification followed by NaOCl treatment additively increased germination to 67%, a response that was associated with marked corrosion of the lemma margin in the distal region of the caryopsis, as observed by SEM. Prechilling the seeds following acid scarification and NaOCl treatment further increased germination to 79%. Acid scarification, NaOCl and prechilling combined almost doubled the final emergence, and greatly increased seedling shoot dry mass in both warm and cool postsowing environments. However, the effectiveness of these seed treatments was lost in seeds stored for 32 months (afterripened).

(1248)

Hayward, P. (1989). Choice Colorado perennials. *Am Nurseryman* 169(7): 30-37.

(1182)

Heide, O. M. (1995). Dual induction control of flowering in *Leucanthemum vulgare*. *Physiologia Plantarum* 95(1): 159-165.
The perennial herb *Leucanthemum vulgare* (oxeye daisy) has a dual induction requirement for flowering. The primary induction is a typical low temperature vernalization response. Temperatures up to 15°C are effective, and the optimum is 6-9°C. Short days (SD) during low temperature exposure enhanced primary induction, but SD could not fully substitute for low temperature in primary induction. At optimum temperatures about 6 weeks exposure were required for 100% flowering, but the flowering response increased with increasing exposure up to 12 weeks, especially at higher

temperatures. Seedlings have a short juvenile phase of about 4 weeks. Populations with origin ranging from 59 to 69°N in Norway did not vary in their primary induction requirements. Long days (LD) were required for inflorescence initiation and stem elongation at 9°C. At 21 and 15°C some plants initiated and developed inflorescences in SD, but the inflorescences were sessile and their development strongly delayed. More than 16 LD cycles were required for normal stem elongation (bolting).

(631)

Heims (1999). *Heuchera heyday*. American Nurseryman (March 1): 30 - 32, 34.
With wonderful flowers, amazing foliage, and good disease and insect resistance, new breed of *Heuchera* are valuable landscape assets

(664)

Heins, R. D., A. C. Cameron, et al. (1997). Controlled flowering of herbaceous perennial plants. International Symposium on Plant Production in Closed Ecosystems. E. Goto, K. Kurata, M. Hayashi and S. Sase. Dordrecht, Netherlands, Kluwer Academic Publishers: 15 - 31.

(1067)

Herman, R. M. (1992). Perennial favorites. *Am Nurseryman* 176(12): 99-102.
A look at some recent European perennial introductions: *Anemone hepatica* x *hybrida* 'Pamina', *A. x hybrida* 'Honorine Hobert', *A. x hybrida* 'Queen Charlotte', *Aster* 'Lovely', *Calamintha nepeta*, *Geranium x cantabrigiense*, *G. macrorrhizum*, *Rudbeckia nitida* 'Herbstsonne', *Salvia officinalis* 'Berggarten'

(1082)

Herrick, T. A. and L. P. Perry (1995). Controlled freezing of twenty-three container-grown herbaceous perennials. *Journal of Environmental Horticulture* 13(4): 190-193.
Twenty-three containerized herbaceous perennials were acclimatized to ambient outdoor temperature and photoperiod until 19 Nov., when they were moved into a greenhouse and held at 3°C until 15 Feb. At that time, plants were exposed for 30 min to a range of subzero temperatures, and returned to the greenhouse for forcing. Plants were rated for survival and saleability following 6 weeks regrowth at 15°, using a subjective scale of 1 to 5 (1 = worst, 5 = best, 3 and above considered saleable). Of the 23 perennials studied, 15 survived after exposure to at least -8°, however, 40% of the

species and cultivars surviving at this temperature sustained a level of injury which rendered them unsaleable. Most plants were rated saleable at treatment temperatures 3-6° warmer than their respective lowest survival temperatures (LST's). *Phlox* cultivars *Chattahoochee* and *Morris Berd*, and *Tiarella* cv. *Laird of Skye* remained saleable after exposure to -11°. *Campanula takesimana*, *Heuchera americana* cv. *Dales Strain*, *Penstemon fruticosus* cv. *Purple Haze*, *Rosmarinus officinalis* cv. *Arp*, *Tiarella* cv. *Running Tapestry*, and *Tiarella cordifolia* cv. *Slick Rock* remained saleable after exposure to -8°. *Erodium reichardia* cv. *Roseum*, *Hebe macrocarpa* cv. *Margaret*, and *Verbena* cv. *Homestead Purple* remained saleable after exposure to -5°. Only the unfrozen controls of *Houttuynia cordata* cv. *Chameleon* and *Thelypteris kunthii* remained saleable. Treatment means for *Ceratostigma plumbaginoides* were not significantly different and all 6 *Hibiscus* cultivars (*Blue River II*, *Disco Belle Pink*, *Disco Belle Rose Red*, *Disco Belle White*, *Lord Baltimore* and *Southern Belle*) failed to survive any of the temperature treatments. In general, plants showed a gradual decline in saleability with decreasing temperature.

(1100)

Herrick, T. A. and L. P. Perry (1997). Influence of freeze acclimation procedure on survival and regrowth of container-grown *Campanula takesimana* Nakai. *HortTechnology* 7(1): 43-46.
Crown divisions of *C. takesimana* were potted on 1 September 1994 and grown under natural outdoor conditions (in Vermont) until 19 November, when they were moved into a 3°C greenhouse. On 15 February 1995, 10 plants were randomly assigned to each of 4 temperature treatments (-5, -8, -11 and -14°), each using of 4 freeze acclimatization procedures designated A-D: group A plants were held at treatment temperatures for 30 min; group B plants were first subjected to 3 alternating freeze-thaw cycles (-3° for 24 h, 3° for 24 h), then held at treatment temperatures for 30 min; plants in group C were held at -1° for 14 days then exposed to treatment temperatures for 30 min; group D plants were held at treatment temperatures for 48 h. A control group was held at 3° for the duration of the study. Following 6 weeks of regrowth at 15°, plants were rated for survival and regrowth quality relative to unfrozen controls. At treatment temperatures of -8° or less, acclimatization procedure significantly influenced survival and regrowth quality. Plants exposed to 3 freeze-thaw cycles had the highest regrowth ratings at treatment temperatures less than -5°, with no loss

in marketability following exposure to -11° . In addition, all plants exposed to freeze-thaw cycles thrived following controlled freezing, whereas those in each of the other groups displayed a decline in survival with decreasing treatment temperatures. Holding plants for 14 days at -1° had no beneficial effect on survival or regrowth quality compared with controls. Increasing exposure duration from 30 min to 48 h significantly reduced regrowth quality at treatment temperatures of -8 and -11° .

(1178)

Hicks, S. and R. Turkington (2000). Compensatory growth of three herbaceous perennial species: the effects of clipping and nutrient availability. *Canadian Journal of Botany* 78(6): 759-767. The continuum of responses model (CRM) and the growth rate model (GRM) make conflicting predictions about the effects of soil nutrient availability on the resilience of plants to herbivory. A factorial experiment was conducted in the understory of the boreal forest near Kluane lake, Yukon territory, Canada to examine the effects of fertilization and simulated herbivory on the rate and amount of regrowth of three herbaceous perennial species (*Achillea millefolium* L., *Festuca altaica* Trin., and *Mertensia paniculata* (Aiton) G. Don.). As clipping intensity increases various measures of plant performance decrease. Fertilization reduces the ability of clipped plants to compensate for biomass loss regardless of species and growth measure. Under natural soil fertility levels in this study, *M. paniculata* is more likely to compensate for leaf loss than *A. millefolium* and *F. altaica*. Contrary to the findings of previous field studies, the compensatory responses of the three species studied were most consistent with the predictions of the GRM. Plants in our study sites grow in nutrient-poor soils, whereas the majority of compensatory studies have been carried out on herbaceous or woody plants in temperate regions. Resources are generally more abundant in temperate zones than in boreal forest zones, and the GRM may be a better predictor of compensatory ability of plants growing in naturally nutrient-deficient soils.

(1087)

Hitchmough, J. (1995). Perennial pleasures in the urban sward. *Horticulturist* 4(2): 2-9. The selection of herbaceous perennials for meadow or tussock grasslands on urban sites, their establishment and management and the control of self-seeding are discussed.

(60)

Holcomb, E. J. and D. J. Beattie (1990). Growth retardants for perennials. *Proceedings of the Plant Growth Regulator Society of America*, Saint Paul, Minnesota, Lake Alfred, Fla. : The Society.: 164-169.

Perennials could be grown as potted plants, but are normally too tall. The objective of this research was to evaluate how several perennial species would respond to growth retardant application. Perennials were obtained as corms, tuberous roots, seedlings, rooted cuttings, bulbs, or crowns. When the plants were actively growing, growth retardants were applied either as a drench or a foliar spray. The effects of growth retardants varied with species, growth retardant, and method of application. For example, daminozide spray controlled the height of platycodon, uniconazole drench reduced the height of astilbe, coreopsis, delphinium, and liatris, while a uniconazole spray was effective on coreopsis and delphinium. Both uniconazole and paclobutrazole controlled the height of hybrid lilies. The flowering height of perennials in containers can be restricted, except for liatris, if the correct growth retardant and rate is chosen.

(1077)

Holcomb, E. J. and D. J. Beattie (1990). Growth retardants for perennials. *Proceedings of the Plant Growth Regulator Society of America* 17: 164-169. In attempts to produce garden perennials as pot plants, the growth retardants daminozide, ancymidol, paclobutrazol or uniconazole were applied at various concentrations to 6 perennials (*Liatris spicata* cv. Kobold; *Platycodon grandiflorus* cv. Blue; *Delphinium* cv. Blue Spring; *Coreopsis verticillata* cv. Moonbeam; *Lilium [maculatum]* cv. Sunray and *Astilbe* cv. Avalanche). The plants were obtained as corms, root tubers, seedlings, rooted cuttings, bulbs or crowns, respectively, and were treated with the growth regulators as drenches or foliar sprays when actively growing. The results are tabulated. It was found that, apart from *L. spicata*, the flowering height of these species could be restricted if the appropriate retardant and rate of application was used.

(1232)

Holland, S., T. R. Kemp, et al. (1981). Cytokinin activity of root tissue during chrysanthemum development. *HortScience* 16(1): 93-94. Cytokinin activity was found in the roots of *Chrysanthemum morifolium*, cv. Polaris, cultured by a nutrient film technique and assayed at 3

stages of plant development, viz. the young actively growing stage, the mature flowering stage, and the senescing stage (with dried flowers). This perennial species, therefore, differed from certain annual species where cytokinin activity declined rapidly during senescence.

(1180)

Holmgren, N. H. (1992). Two new species of *Viola* (Violaceae) from the Intermountain West, USA. *Brittonia* 44(3): 300-305.

Viola lithion and *V. frank-smithii* are rock-dwelling endemics that belong to the North American perennial, caulescent, simple-leaved, blue-, purple-, or white-flowered group of species. *V. lithion*, from the White Pine and Pilot mountain ranges of eastern Nevada and adjacent Utah, belongs to section *Chamaemelum* subsection *Canadenses*. It most closely resembles the reniform-leaved, Olympic Mountain *V. flettii*, together with which it possibly shares an ancestry with the widespread and allopatric *V. canadensis*. *V. frank-smithii*, restricted to the Logan Canyon drainage of the Bear River Range in northern Utah, belongs to section *Rostellatae* subsection *Rosulantes*. It comes closest morphologically to *V. howellii* of the Coast Range, but likely evolved from the widespread *V. adunca* or a common ancestor. Both species are formally described and illustrated and a key to species in both sections *Chamaemelum* and *Rostellatae* is supplied.

(368)

Hood, L. R. and J. E. Klett (1992). Preemergent weed control in container-grown herbaceous and woody plants. *Journal of Environmental Horticulture* 10(1): 8-11.

Six herbicides were applied to four woody and two herbaceous plant species to evaluate weed control effectiveness, effect on plant growth and phytotoxicity level. Surflan at 2.3, 4.5, 6.8 kg ai/ha, Devrinol at 5.5, 9.1, 13.6 kg ai/ha, and Dual, Rout, and Snapshot at 3.4, 6.8, 10.2 kg ai/ha were applied to container-grown green ash, and white birch. Additionally, Surflan at 2.3, 4.5 kg ai/ha, Ronstar and Devrinol at 5.52, 9.1 kg ai/ha, Dual and Rout at 3.4, 6.8 kg ai/ha were applied to container-grown Tatarian maple, virginian mock orange, daylily, and clematis. Weed seed sown in both experiments included: yellow foxtail, barnyardgrass, annual bluegrass, common chickweed, shepardspurse and common groundel. Plants were grown in 2.5 L black plastic containers in a medium of sandy loam topsoil, plaster sand and sphagnum peat (1:1:1 by volume). Good weed control occurred in most cases

with all herbicides except Devrinol and Dual. No visual foliage injury occurred in any treatment but significant growth reduction was observed with the 10.2 kg ai/ha rate of Snapshot with white birch. Growth reduction of tatarian maple was also observed with 6.8 kg ai/ha rate of Dual and 4.25 kg ai/ha rate of Surflan.

(1199)

Horvath, J., G. Loebenstein, et al. (1996).

Ornamental *Physalis* species as perennial virus hosts. Ninth international symposium on virus diseases of ornamental plants, Herzliya, Israel, 17-22 March, 1996 No. 432: 204-210.

In 4 ornamental *Physalis* species, 38 new experimental host-virus relations were detected. After mechanical inoculation with 19 viruses from 12 virus groups *P. alkekengi* was locally and systemically susceptible to 10 viruses, *P. ixocarpa* to 14 viruses, *P. peruviana* to 4 viruses and *P. pubescens* to 2 viruses. When *P. alkekengi* was inoculated with broad bean wilt fabavirus (BBWV) and *P. peruviana* was inoculated with alfalfa mosaic alfamovirus (AMV), potato aucuba mosaic potexvirus (PAMV) and potato Y potyvirus (PVY) only systemic vein clearing and mosaic were established. *P. ixocarpa* was only locally susceptible to tobacco necrosis necrovirus (TNV), *P. peruviana* to tobacco rattle tobnavirus (TRV) and *P. pubescens* to TNV and TRV. In those cases where the perennial ornamental *Physalis* species were infected systemically it is likely that natural infections with these viruses also occur.

(1233)

Hosoki, T. (1983). Breaking dormancy with ethanol and storage. *HortScience* 18(6): 876-878. Ethanol vapour treatment broke dormancy in *Gladiolus* and *Freesia* spp., *Lilium longiflorum*, *Zingiber mioga*, *Platycodon grandiflorum*, *Paeonia suffruticosa* and *Prunus persica* but its effectiveness depended on the depth of dormancy. Low or high temperature storage improved ethanol effectiveness.

(1201)

Hosoki, T., K. Ohta, et al. (1995). In vitro propagation of thin-leaf sunflower (*Helianthus decapetalus* L.). New ornamental crops and the market for floricultural products, XXIV International Horticultural Congress, Kyoto, Japan, 21-27 August 1994 No. 397: 125-128. In vitro propagation of *H. decapetalus* was achieved by subculturing shoot sections with nodes on MS medium supplemented with 0.1 mg BA/litre. A multiplication rate of 4.9 per 22-day culture

period was achieved, resulting in a theoretical yield of 110.4 billion shoots from a single shoot tip in one year. Shoots elongated from these in-vitro cultured nodes could be rooted on MS medium with 0.1 mg IBA/litre. Plants produced were readily acclimatized and duly flowered in a greenhouse.

(779)

Huang, N., K. A. Funnell, et al. (1999). Vernalization and growing degree-day requirements for flowering of *Thalictrum delavayi* 'Hewitt's Double'. *HortScience* 34(1): 59-61. Vernalization and growing degree-day (GDD) requirements of *T. delavayi* cv. Hewitt's Double were investigated by exposing crowns to cold storage for 0, 3, 6, 9, 12 or 15 weeks at 8°C, and subsequently planting them in a heated greenhouse under long-day conditions. Cumulative vernalization of crowns was complete after 6 weeks of cold storage at 8°C. The time to flower, including time at 8°C, was 3338 GDD (base temperature of 0°C) without vernalization and 2802 GDD after complete vernalization. Commercial recommendations for rapid and predictable flowering of *T. delavayi* cv. Hewitt's Double should include cold storage of crowns for a minimum of 6 weeks at 8°C as part of the 2802 GDD during vernalization and forcing.

(495)

Hutchinson, M. J., S. J. Murch, et al. (1996). Morphoregulatory role of thidiazuron: evidence of the involvement of endogenous auxin in thidiazuron-induced somatic embryogenesis of geranium (*Pelargonium X hortorum* Bailey). *J. Plant Physiol.* 149(5): 573-579. Thidiazuron-induced somatic embryogenesis in hypocotyl cultures of geranium (*Pelargonium X hortorum* cv. Scarlet Orbit Improved) consists of an induction phase on medium containing thidiazuron (TDZ) at 10 or 20 µmol/litre followed by an expression phase on a basal medium lacking growth regulators. The induction and development of somatic embryos were found to be closely related to levels of endogenous and exogenous auxin. Inclusion of the auxin-action inhibitor, 2-p-(chlorophenoxy)-2-isobutyric acid (PCIB), and the auxin-transport inhibitor, TIBA, in a TDZ-induction medium decreased embryogenic response of the cultures by different mechanisms. The decrease of the embryogenic response in the presence of PCIB was accompanied by a corresponding decrease in endogenous levels of auxins, cytokinins, and ABA. These changes in the profiles of endogenous plant growth regulators

were not evident when TIBA was used. High concentrations of exogenous IAA in the expression medium suppressed the development of somatic embryos. Although the precise mode of action of TDZ is unknown, it is suggested that TDZ modulates endogenous auxin metabolism during somatic embryo development in geranium hypocotyl cultures.

(621)

Iles, J. K. and N. H. Agnew (1993). Responses of five container-grown herbaceous perennial species at laboratory freezing. *HortTechnology* 3(2): 192-194.

Containerized plants of *Gaillardia X grandiflora* [G. aristata], *Physostegia virginiana* cv. Summer Snow, *Salvia X superba* cv. Stratford Blue, *Tanacetum coccineum* cv. Robinsons Mix and *Veronica repens* were placed in a freezer at 2±2°C on 13 Dec. After a few weeks, plants were subjected to temperatures from 0 to -18°, reached by lowering the freezer temperature by 2°/h. Control plants remained at 2°. Plants remained at treatment temperatures until the temperature of the growing medium had stabilized. After treatment, plants were returned to 2° to thaw gradually, then transferred to a greenhouse at 21°. Following exposure to -10°, survival percentage was 88% for *T. coccineum* and 100% for the other species; below this temperature, survival percentages generally decreased, although *P. virginiana* showed 100% survival at -16°. Except for *G. grandiflora*, plants sustained no significant injury when exposed to -10°. Regrowth DW was poor in all species following exposure to -12°, although the degree of injury varied. Identification of the overwintering organs responsible for the perennial nature of these species will help to clarify how they withstand freezing temperatures.

(1142)

Iles, J. K. and N. H. Agnew (1993). Responses of five container-grown herbaceous perennial species to laboratory freezing. *HortTechnology* 3(2): 192-194.

Containerized plants of *Gaillardia X grandiflora* [G. aristata], *Physostegia virginiana* cv. Summer Snow, *Salvia X superba* cv. Stratford Blue, *Tanacetum coccineum* cv. Robinsons Mix and *Veronica repens* were placed in a freezer at 2±2°C on 13 Dec. After a few weeks, plants were subjected to temperatures from 0 to -18°, reached by lowering the freezer temperature by 2°/h. Control plants remained at 2°. Plants remained at treatment temperatures until the temperature of the growing medium had stabilized. After treatment,

plants were returned to 2° to thaw gradually, then transferred to a greenhouse at 21°. Following exposure to -10°, survival percentage was 88% for *T. coccineum* and 100% for the other species; below this temperature, survival percentages generally decreased, although *P. virginiana* showed 100% survival at -16°. Except for *G. grandiflora*, plants sustained no significant injury when exposed to -10°. Regrowth DW was poor in all species following exposure to -12°, although the degree of injury varied. Identification of the overwintering organs responsible for the perennial nature of these species will help to clarify how they withstand freezing temperatures.

(1065)

Iles, J. K. and N. H. Agnew (1993). Determining cold hardiness of *Heuchera sanguinea* Engelm. 'Chatterbox' using dormant crowns. *HortScience* 28(11): 1087-1088.

Dormant, intact crowns of the herbaceous perennial *H. sanguinea* cv. Chatterbox were placed in moist cheesecloth, wrapped in aluminium foil, and subjected to -4, -6, -8, -10, -12, -14, -16 or -18°C in a programmable freezer. Crown samples were removed after tissue temperature had stabilized at each treatment temperature, and allowed to thaw for 24 h at 2° before planting in containers and transferring to the greenhouse at 21°. Regrowth quality ratings and DM measurements after 60 days decreased linearly with temperature. No regrowth was evident from any crown exposed to -12°. Freezing dormant plant crowns proved an efficient and reliable technique for estimating cold hardiness of this cultivar.

(1048)

Iles, J. K. and N. H. Agnew (1995). Forcing herbaceous perennials to flower after storage outdoors under a thermoblanket. *HortTechnology* 5(3): 239-243.

Nine herbaceous perennial species were evaluated for use as flowering potted plants for late winter and early spring sales. Plugs were established in 14-cm (0.8-litre) round plastic containers, grown for one season and covered with a thermoblanket for winter. Five plants of each species were transferred to a 21±3°C glasshouse for forcing under natural daylengths at six 10-day intervals beginning on 1 Dec. 1993. *Arabis sturii*, *Phlox X chatahoochee* [*Phlox* cv. *Chatahoochee*], *Platycodon grandiflorus* cv. *Sentimental Blue* and *Veronica* cv. *Sunny Border Blue* flowered out of season without supplemental lighting. *Armeria maritima* cv. *Alba* and *Chrysogonum virginianum*

also flowered; however, their floral displays were less effective. *Bergenia cordifolia* cv. *New Hybrid* did not flower and *Achillea X lewisii* cv. *King Edward* and *Dianthus X allwoodii* cv. *War Bonnet* only flowered sporadically. These last 3 species are not recommended for forcing out of season using this vernalization method.

(1221)

Iles, J. K. and N. H. Agnew (1995). Seasonal cold-acclimation patterns of *Sedum spectabile* x *telephium* L. 'Autumn Joy' and *Sedum spectabile* Boreau. 'Brilliant'. *HortScience* 30(6): 1221-1224. Electrolyte leakage and regrowth were measured from September through January to determine cold hardiness of *Sedum spectabile* x *telephium* L. 'Autumn Joy' and *Sedum spectabile* Boreau. 'Brilliant' plants grown outdoors in central Iowa. Crowns were subjected to 0, -3, -6, -9, -12, -15, -18, -21, -24 or -27°C. Regrowth tests were performed on whole crowns and electrolyte leakage was determined on excised tuberous root and crown tissue. Both cultivars were killed at -3°C in September, but they acclimated gradually through January. Maximum hardiness was achieved in January with killing temperatures of -27°C for 'Autumn Joy' and -21°C for 'Brilliant'. Regrowth quality ratings were significantly correlated with crown and tuberous root electrolyte leakage measurements although the relationship was stronger for 'Autumn Joy'.

(1086)

Iles, J. K., N. H. Agnew, et al. (1993). Evaluation of structureless overwintering systems for container-grown herbaceous perennials. *Journal of Environmental Horticulture* 11(2): 48-55. Five structureless overwintering systems were evaluated in 1989 and 1990 for temperature moderation and protection of 18 species of container-grown herbaceous perennials from low-temperature injury. Two light-excluding treatments (30-cm thick layer of straw between 2 layers of 4-mm thick, white polyethylene, or 18-cm deep, in-ground beds protected with 1 layer of 4-mm thick, white polyethylene and 30 cm of woodchips) provided the greatest moderation of low winter and high early spring temperatures, but also resulted in severe etiolation. A bonded white polyethylene/microfoam overwintering blanket (thermoblanket) with translucent properties provided comparable plant survival percentages despite dramatic temperature extremes recorded beneath this cover and, in late winter, created an environment conducive to moderate plant growth without formation of etiolated tissue. Based on

shoot DW measurements, the species deriving the most benefit from winter covers, regardless of covering treatment, were *Coreopsis verticillata* cv. Zagreb, *Delphinium elatum* cv. Pacific Hybrid, *Physostegia virginiana* cultivars Pink Bouquet and Summer Snow, *Sedum* cultivars Autumn Joy and Brilliant, and *Veronica spicata* cv. Icicle.

(1093)

Iles, J. K., W. R. Graves, et al. (1998). Midwestern retail garden centers identify satisfaction/dissatisfaction with supplying wholesale nurseries. *Journal of Environmental Horticulture* 16(4): 243-247.

A December 1996 survey was conducted to assess the attitudes of Midwestern US retail nursery operators concerning current marketing, promotion, sales, and service practices of their wholesale nursery stock suppliers. Completed questionnaires were received from 290 individuals (42.2% response rate). Respondents indicated quality of plant materials (96.5%), availability of plant materials in desired quantities (67.8%), wide assortment of plant materials (53.5%), and price of nursery stock (40.3%) were very important reasons for conducting business with a wholesale supplier. The majority of respondents said they were 'very satisfied' with the condition of bare-root trees and shrubs (75.1%), bedding plants (72.9%), herbaceous perennials and ornamental grasses (72.2%), container-grown trees and shrubs (72.0%), and balled-and-burlapped trees and shrubs (67.4%) shipped by their wholesale supplier. Over one-half (56.5%) also said they were 'very satisfied' with aquatic plant shipments. On those occasions when plants arrived in unsatisfactory condition, the most frequently cited problems were, dry bare-root stock (34.4%), physically damaged container-grown stock (56%) and balled-and-burlapped stock (40%), undersized herbaceous plants (20.3%), and aquatic plants damaged in transit (12.1%). In general, retailers were most favourably impressed with the respectful and helpful way wholesalers attempted to meet their business needs (57.1%). Retailers were most frustrated with shortages, unauthorized substitutions, and last-minute cancellations (31.9%).

(1080)

Indyke, H. (1978). Chemical renovation of large college campus. *Weeds, Trees and Turf* 17(3): 34-38.
Estimates of \$59 290 for reseeding 35 acres and \$243 939 for laying turf promoted interest in chemical renovation using glyphosate and

reseeding. Glyphosate applied in August gave complete control and the reseeded grasses had established by the end of October. The herbicide and grass seed cost \$5950.

Renovation of turf composed of coarse grasses and broad-leaved weeds in New Jersey was carried out without soil disturbance, using glyphosate on 15 August and overseeding 7 days later with a mixture of smooth-stalked meadow grass [*Poa pratensis*], Chewings fescue [*Festuca rubra*] and perennial ryegrass [*Lolium perenne*]. Turf was well established by the end of October.

(635)

Iversen, R. R. (1994). Forcing perennial plants: a flower show guide. *Public gard* 9(4): 30-32.

(1249)

Iversen, R. R. and T. C. Weiler (1989). Forcing the issue: a guide to forcing garden perennials into bloom for flower show exhibitions. *Am Nurseryman* 169(8): 95-103.

(1122)

Iversen, R. R. and T. C. Weiler (1994). Strategies to force flowering of six herbaceous garden perennials. *HortTechnology* 4(1): 61-65.
Potted Platycodon grandiflorus cv. *Mariesii*, *Coreopsis* cv. *Moonbeam*, *Echinops* cv. *Taplow Blue*, *Campanula persicifolia*, *Lysimachia clethroides* and *Phlox* cv. *Fairy's Petticoat* plants were cold-treated at 4.5°C in walk-in refrigerators (with incandescent light for species with evergreen basal foliage) for 0, 6 or 12 weeks. After cold storage, plants were grown in 8-, 16- or 24-h photoperiods in a greenhouse at day/night temperatures of 18.3/15.5°. From the results, it was concluded that the approximate minimum times required for treatment and forcing for out-of-season flowering were as follows: 5 months for *P. grandiflorus* and *C. persicifolia*, 9 weeks for *Coreopsis*, 6.25 months for *L. clethroides* and 4.5 months for *Phlox* and *Echinops*.

(1133)

Jha, R. R., T. K. Pan, et al. (1993). Picks from the wild - the variegated novelties. *Indian Horticulture* 37(4): 4-5.

Three wild foliage plants were discovered in the Rajmahal Hills of Bihar at 150-200 m elevation, soil pH 7.5-8.4, rainfall 1350-1450 mm and temperature 20-30°C. *Lepidagathis incurva*, (Acanthaceae) grows to 40 cm, is much branched, with linear-lanceolate brown striped deep green leaves and 7 mm diameter flowerheads. Seeds were

sown in August and it is recommended for growth in flower beds. *Tetrastigma lanceolarium* var. *variegatum*, (Vitaceae [Vitidaceae]), is 30 cm tall, has green cylindrical and branched culms and pedately 5-foliate, oblong-lanceolate, acuminate leaves with white patches on both surfaces. It can be grown in pots throughout the year. *Thunbergia grandiflora* var. *variegata* [Thunbergiaceae] is a small, tufted perennial growing to 20 cm in height. It bears variegated foliage from August to November. Plants are rhizomatous and dormant during winter and suitable for pot growth.

(1256)

Johnson, A. M. and T. Whitwell (1997). Selecting species to produce wildflower seeds. HortTechnology 7(4): 415-417.

Twenty-nine annual and perennial wild flower species were evaluated for commercial seed production potential in South Carolina. Species selection was based on adaptability to southeastern conditions and potential for use in wild flower sod. Potential for seed production was based on seed maturation ratings, percentage germination 4-6 weeks after harvest, and yield. Individual species were sown into 1-m² plots on 7 October. Seeds were collected, cleaned and counted, and viable seed yield was calculated based on seed germination and weight of 100 seeds. Species with potential for production were *Hesperis matronalis* (2605 lb/acre), *Monarda citriodora* (1247 lb/acre), *Silene armeria* (1122 lb/acre), *Bidens aristosa* (41 lb/acre), *Centaurea cyamus* (823 lb/acre), *Coreopsis tinctoria* (185 lb/acre), *Gypsophila elegans* (120 lb/acre), *Ipomopsis rubra* (2301 lb/acre) and *Rudbeckia hirta* (500 lb/acre).

(1255)

Johnson, A. M. and T. Whitwell (1997). Selecting species to develop a field-grown wildflower sod. HortTechnology 7(4): 411-414.

In trials in the coastal plain region of South Carolina, 29 annual and perennial wild flower species were evaluated for sod development based on ratings for appearance, root mat density and stability following undercutting and storage, as well as performance after replanting. Species selection was based on the lack of a large taproot, adaptability to the southeastern climate, flowering period and potential for surviving root undercutting. Species were sown in autumn and spring, and leaf area and root mass samples were compared. Wild flower sod was undercut at a 5-cm depth in March (autumn-sown plots) and May (spring-sown plots) and then stored on clear

plastic for 7 weeks under overhead irrigation and replanted. Autumn-planted species had a higher survival rate than spring-planted ones. Species selected for sod development were *Achillea millefolium*, *Chrysanthemum leucanthemum* [*Leucanthemum vulgare*], *Coreopsis lanceolata*, *Coreopsis tinctoria*, *Gaillardia aristata*, *Monarda citriodora*, *Rudbeckia hirta* and *Verbena tenuisecta*. With a view to reducing damage to aerial growth during harvesting, paclobutrazol (50 ppm), daminozide (5000 ppm) and uniconazole (25 ppm) were tested for their ability to reduce top growth of 8 greenhouse-grown wild flower species. Uniconazole resulted in a limited amount of growth control in *R. hirta*, *M. citriodora*, *C. lanceolata* and *C. tinctoria*.

(1139)

Joustra, M. K. and P. A. W. Verhoeven (1984). Rooting hardwood cuttings of certain woody perennial species. Plant Propagator 30(2): 3-4. Growth regulator treatments, growing media and greenhouse conditions which resulted in the highest percentage rooting in hardwood cuttings of *Acer palmatum*, *Cornus florida*, *C. kousa* var. *chinensis*, *Corylopsis pauciflora*, *Corylus maxima*, *Hamamelis mollis*, *H. virginiana*, *Ligustrum quihoui*, *Prunus triloba* and roses (cv. Dagmar Hastrup) are described.

(1165)

Kalisz, S., F. M. Hanzawa, et al. (1999). Ant-mediated seed dispersal alters pattern of relatedness in a population of *Trillium grandiflorum*. Ecology 80(8): 2620-2634. It is examined how ant-mediated seed dispersal affects the number and relatedness of seeds in both dispersed and undispersed aggregations and how these patterns influence seedling emergence in the long-lived perennial *Trillium grandiflorum*. Experimental hand-pollinations in Kalamazoo County, Michigan, over two years demonstrated that selfing is extremely rare and suggested that self-incompatibility (SI) is a likely explanation. The multi-locus outcrossing estimate ($t_m = 1.05 \pm 0.056$) confirms this result and also suggests that seeds within a fruit are likely to have the same pollen parent. Thus, a highly outcrossing mating system is the initial determinant of relatedness among seeds within a fruit. Uniquely coded, radiolabelled seeds from 30 and 40 fruits were tracked in 1991 and 1992, respectively, to determine how dispersal alters this initial relatedness of seeds. Of the 335 and 876 seeds labelled in these two years, 63 and 76% were recovered postdispersal and 19 and 23% of the recovered seeds were dispersed > 10 cm

from the maternal parent in the first and second years, respectively. In both years, ant-mediated dispersal reduced the number of seeds near the maternal parent. However, the effect of seed dispersal on the number of seeds in aggregations varied among years. Ant-mediated dispersal increased the number of seeds in dispersed aggregations in the first year and decreased the number in the second year. The average seed dispersal distance also differed between years: 2.41 m (± 0.33) vs. 0.53 m (± 0.06) in years 1 and 2, respectively. Ant-mediated seed dispersal decreased the probability of a seed having a sibling as its nearest neighbour postdispersal by between one-third and one-half. In contrast, seedling emergence was related to neither dispersal nor seed aggregation size in this study. However, the fitness effects of dispersal may be important later in the life cycle of this long-lived species and as such were undetected. One scenario is that plants derived from seeds dispersed out of their sibling relatedness group may gain minority advantage both in terms of mating success (if the population is SI) and other frequency-dependent processes like disease resistance.

(1159)

Karron, J. D., R. Tucker, et al. (1995). Comparison of pollinator flight movements and gene dispersal patterns in *Mimulus ringens*. *Heredity* 75(6): 612-617.

Pollinator movements and pollen-mediated gene dispersal were quantified in experimental populations of square-stemmed *Mimulus ringens*, a wetland perennial herb with a mixed mating system. Each population consisted of genets with unique multilocus combinations of homozygous genotypes, facilitating assignment of paternity to all sampled seeds. Replicate arrays were planted at each of three spacings spanning the range of densities typically observed in natural *M. ringens* populations. In all six arrays the distribution of gene dispersal distances differed significantly from the distribution of pollinator flight movements. The mean gene dispersal distance was 1.46 times as far as the mean pollinator flight distance. These differences were probably caused by pollen carryover as bumblebees (*Bombus*) visited up to 12 *M. ringens* plants on a single foraging trip. Although gene movements exceeded pollinator flight distances, estimates of neighbourhood size were consistently low, ranging from 1.66 to 5.53. Therefore, high levels of random local genetic differentiation are likely in this species.

(1081)

Keever, G. J. (1994). BA-induced offset formation in *hosta*. *Journal of Environmental Horticulture* 12(1): 36-39.

Axillary and rhizomic budbreak and offset formation in *Hosta sieboldiana* were promoted by a single foliar application of BA at 125-4000 p.p.m. or drench application at 5-120 mg a.i./0.8-litre pot, compared with an untreated control. Based on offset counts following various periods of dormancy, optimal foliar rates ranged from 2000 to 3000 p.p.m. and drench rates from 20 to 40 mg a.i./0.8-litre pot. Foliar application of 3000 or 4000 p.p.m. BA or drenching with 80, 100, or 120 mg a.i./pot induced marginal necrosis within 2 weeks after treatment; however, growth following dormancy appeared normal. Generally, growth indices were not affected by foliar application of BA, but decreased with increasing rates of drench-applied BA.

(1094)

Keever, G. J. and T. J. Brass (1998). Offset increase in *hosta* following benzyladenine application. *Journal of Environmental Horticulture* 16(1): 1-3.

A single foliar application in July of benzyladenine (BA) at 1250-3750 ppm stimulated axillary and rhizomic budbreak and offset formation in *Hosta sieboldiana*. Plants with no initial offsets formed a similar number of offsets as those with 1 initial offset but produced 143% more offsets than plants with 2 or 3 initial offsets. Growth index was either not affected or increased by BA application. Plant appearance was enhanced by late season offset formation in BA-treated plants.

(1224)

Kelly, J. W. and T. W. Starman (1990). Postharvest handling of *Physostegia purpurea* cut flowers. *HortScience* 25(5): 552-553.

P. purpurea is a native herbaceous perennial that has potential as a field-grown cut flower. The stems were harvested with one third of the florets open and were recut under water in the laboratory. Fresh cut flowers treated with silver thiosulphate (STS) and held in a 2% preservative solution (Floever) lasted 14 days, while control stems in deionized water (DI) lasted 6 days. Cut stems placed in darkness at 0°C for 1 week had 8 days of vase life after removal from storage and treatment with STS and preservative, while stems held in DI after storage lasted only 4 days. Stems held dry at 22.5° and 43% RH for 8 h before being placed in a preservative solution had a similar vase life to flowers placed in the preservative solution immediately after harvest.

(1210)

Khawaja, H. I. T. (1988). A new interspecific *Lathyrus* hybrid to introduce the yellow flower character into sweet pea. *Euphytica* 37(1): 69-75. Interspecific crosses were attempted between *L. odoratus* ($2n = 14$) and each of the yellow-flowered species *L. annuus*, *L. hirsutus*, *L. chloranthus* (all annuals and diploid) and *L. pratensis* (perennial with diploid and tetraploid cytotypes). All pollinations involving *L. annuus* and *L. pratensis* were unsuccessful. With the remaining crosses, pollinations were successful in one direction only. *L. hirsutum* X *L. odoratus* gave the best results, viable hybrid seeds being produced in about 50% of the crosses; only one F1 seed was obtained with *L. odoratus* X *L. chloranthus* but the seedling survived and developed into a normal plant which was distinct from both its parents in vegetative and floral characteristics. The morphology and meiotic behaviour are described for these hybrids. Cytologically there were some meiotic irregularities, but the majority of cells showed normal meiosis with 7 bivalents at metaphase I.

(480)

Kjelgren, R. (1996). Irrigation timing of three landscape shrub species based on foliage temperature. *Arboreal Journal* 20(1): 47-57. Changes in foliage temperature with vapour pressure deficit and water stress for three shrub species were investigated for use in irrigation scheduling in landscapes. Midday leaf-minus-air temperature ($T_l - T_a$) and vapour pressure deficit were monitored seasonally for prostrate juniper (*Juniperus horizontalis* 'Wiltonii'), upright juniper (*J. chinensis* 'Hetzi'), and dwarf red-stem dogwood (*Cornus sericea* 'Kelseyii'), positioned as isolated plants or in a massed setting. There was an inverse baseline relationship between $T_l - T_a$ and vapour pressure deficit for all species and both spacings under well-watered conditions. This was consistent with baselines reported for herbaceous crops, but with substantially more scatter. Baseline relationships between spacings were similar for upright juniper and dogwood, but not for prostrate juniper. During a dry-down cycle $T_l - T_a$ exceeded the well-watered baseline for dogwood and upright juniper, signaling incipient water stress. Stress was confirmed in declining predawn leaf water potential and water content of the container media. Due to more water loss, increase in $T_l - T_a$ over the baseline occurred more rapidly in isolated plants in both species. Foliage temperature readings of prostrate juniper were

confounded by sparse canopy that transmitted background radiation. The results suggest that irrigation of certain shrubs in a landscape with dense canopies can be timed to increases in $T_l - T_a$. This method will not work well for shrubs with sparse crowns and under shady, humid conditions.

(632)

Klett, J. (1999). Needs for plant materials in the Rocky Mountain region and the Plant Select program. *Landscape Plant News* 10(1): 5 - 11. The Plant Evaluation and Introduction Program, hereafter referred to as Plant Select, is a cooperative effort between Denver Botanic Gardens (DBG), Colorado State University (CSU), and members of the Green Industry (signed cooperators) with the following purpose:

1. To increase the diversity (genera, species, cultivars) of commercially available plants better suited for the Rocky Mountain Region and beyond.
2. To fulfill the objectives of Denver Botanic Gardens and Colorado State University as educational, research, extension and public service institutions. Each of these institutions is professional in nature and oriented toward serving the areas of greatest societal need with emphasis on state and regional priorities and then beyond.

(782)

Klock Moore, K. A. and T. K. Broschat (1999). Differences in bedding plant growth and nitrate loss with a controlled-release fertilizer and two irrigation systems. *HortTechnology* 9(2): 206-209. In a greenhouse experiment conducted in March 1997, growth of hand-watered and subirrigated cv. Ultra Red petunia (*Petunia* X hybrida) and cv. Super Elfin Violet impatiens (*Impatiens walleriana*) plants, in 400-ml pots filled with peat, vermiculite and perlite (60, 25 and 15% respectively), were compared when grown using 4 controlled-release fertilizer rates and 4 fertilizer placements. Furthermore, the amount of NO_3-N leached from hand-watered plants was compared with the amount captured by the subirrigation system. Before planting, Osmocote (14N-6.2P-11.6K; 4-month release) was either top-dressed (TD), layered in the middle of the pot (M), layered at the bottom of the pot (B), or incorporated throughout (I) the substrate at 1.25, 2.5, 5.0 or 7.5 kg/m³. Shoot dry mass of petunia plants was similar between both irrigation systems and among the 4 fertilizer placements. Subirrigated petunias fertilized with 2.5 kg/m³ had similar shoot dry mass to hand-watered petunias fertilized with 7.5 kg/m³. Hand-watered impatiens had greater shoot dry mass than subirrigated impatiens. Hand-

watered *impatiens* also had greater shoot dry mass in pots with fertilizer at TD, M, or I than with fertilizer at B, but no difference in growth was observed in subirrigated *impatiens* among the different fertilizer placements. Finally, significantly more NO₃-N was leached from hand-watered plants than was captured with the subirrigation systems.

(1098)

Knee, M., R. A. Brake, et al. (1999). Growth of ornamental plants in compacted soils and media. Special Circular Ohio Agricultural Research and Development Center No. 165: 113-119.

This study investigated the ability of a number of Ohio native flowering plants to grow in compacted media. In one experiment, 3 native species grew better in moderately compacted media than 5 species of traditional bedding plants. Ability to grow in compacted media seemed to be related to the ability of roots to expand under pressure and not to growth at low-oxygen levels. Digital photography and image analysis showed that 11 of 13 species of prairie grasses and forbs (herbaceous flowering perennials) grew larger in compacted topsoil or greenhouse medium than in uncompacted media. Size differences persisted in the field for the first growing season. Type of medium did not influence size at transplanting, but in the field, seedlings from greenhouse medium grew larger than those from topsoil. Seedlings of these species were larger after growth in untilled plots than in tilled areas.

(1075)

Koreman, P., A. Cameron, et al. (1996). Manipulating photoperiod for height control. *GrowerTalks* 60(10): 58, 60.

The use of a limited induction photoperiod (LIP), in which plants are exposed to a limited number of inductive long days and then returned to normal days, for height control of perennials was investigated. Plants were grown under long days for 2, 3, 4 or 5 weeks before transfer back to 9-h days for finishing. Height was reduced by LIP in *Campanula carpatica* cv. Blue Clips, *Coreopsis grandiflora* cultivars Sunburst and Sunray, *Coreopsis lanceolata* cv. Early Sunrise, *Coreopsis verticillata* cv. Moonbeam and *Echinacea purpurea*, but not in *C. lanceolata* cv. Baby Sun. Baby Sun and Sunray plants given LIP treatment had fewer buds at first flower than continuously lit controls. Below a critical number, fewer long days resulted in shorter plants but also delayed flowering. In another experiment, Early Sunrise plants were given 16 long days and then grown to

flowering under 8 daylengths ranging from 9 to 24 h of light. As daylength after LIP treatment increased, plant height increased. Plants finished under photoperiods of 14 h or less had no delay in flowering but a significant reduction in height; the best quality plants were finished under a 12-h photoperiod. The height reduction appeared to be effective only on internodes on the vegetative portion of the plant.

(1196)

Kozuharova, K. S., A. M. Nikolova, et al. (1997). Investigation on the spermoderm of *Gypsophila* spp. L. *Journal of Herbs, Spices and Medicinal Plants* 5(1): 85-92.

SEM was used to study the ultrastructure of the spermoderm of dried seeds of 4 perennial *Gypsophila* species (collected from Bulgaria): *G. trichotoma*, *G. paniculata*, *G. tekirae* and *G. glomerata*. The spermoderm of *G. trichotoma* and *G. tekirae* were differentiated from each other by the shape of epidermal cells and the surface of periclinal walls, indicating a definitive taxonomic separation range for these 2 species and supporting the concept of a separate range for the 2 taxons. Differences in the spermoderm structure of *G. paniculata* and *G. glomerata* could also be distinguished.

(1213)

Krikorian, A. D., S. S. Cronauer Mitra, et al. (1988). Protoplast culture of perennials. *Scientia Horticulturae* 37(3): 277-293.

Work on the isolation and culture of protoplasts of *Hemerocallis* and *Musa* is reviewed and the particular problems and limitations which are encountered with these genera are described. Tabulated data are presented showing the effects of different media on *Hemerocallis* protoplast cultures.

(1090)

LaMondia, J. A. (1997). Management of *Meloidogyne* hapla in herbaceous perennial ornamentals by sanitation and resistance. *Journal of Nematology* 29(4 Supp): 717-720.

Root pruning of bare-root plants was investigated as a means of reducing spread and establishment of *M. hapla*. Plants previously inoculated with 10 000 eggs/plant were root-pruned to remove either a portion or most of the fibrous root system without removing underground stems, buds, tubers or tuberous roots. Root pruning of *Aconitum*, *Ajuga*, *Anemone*, *Geranium* and *Trollius* significantly reduced or eliminated *M. hapla* galls and egg production in plants, 1 to 4 months after

propagation. Planting *M. hapla*-resistant plants such as *Rudbeckia* and *Aster* into pots infested with 10 000 eggs/pot eliminated *M. hapla* populations after 2 to 6 months of growth. Tomato plants grown after *Rudbeckia* and *Aster* were free of galls and eggs, while bioassay tomatoes grown after susceptible plants such as *Coreopsis*, *Primula* and *Lobelia* were heavily galled with a large number of egg masses. These results demonstrated the potential of sanitation and resistance for management of *M. hapla* in perennials.

(1119)

LaMondia, J. A. (1995). Response of perennial herbaceous ornamentals to *Meloidogyne hapla*. *Journal of Nematology* 27(4supp): 645-648. Sixty-nine herbaceous perennial ornamentals in 56 genera were evaluated for root galling after 2 months in soil infested with *Meloidogyne hapla* under greenhouse conditions. Plants were rated susceptible or resistant based on the number of galls present on the root systems. Thirty-six percent had more than 100 galls on the roots (similar to 'Rutgers' tomato controls) and were rated susceptible. Thirty percent of the plants tested did not have galls or egg masses present on the root system and were rated resistant. The remaining 34% were intermediate in response. Variation in response to *M. hapla* was observed within plant genera and species. The identification of *M. hapla*-resistant perennial ornamentals will aid in management of this nematode in landscapes and production fields.

(1120)

LaMondia, J. A. (1996). Response of additional herbaceous perennial ornamentals to *Meloidogyne hapla*. *Journal of Nematology* 28(4supp): 636-638. Twenty-nine herbaceous perennial ornamentals were evaluated for root galling after 2 months in soil infested with *Meloidogyne hapla* under greenhouse conditions. Plants such as *Asclepias*, *Epimedium*, *Liriope*, *Lithospermum*, *Myosotis*, *Penstemon*, *Sidalcea* [*Sidalcea*], and *Solidago* did not have galls or egg masses present on the root system and were rated as resistant. *Astrantia*, *Boltonia*, *Centranthus*, and *Miscanthus* had more than 100 galls on the roots (similar to Rutgers tomato controls) and were rated susceptible. The remaining plants were intermediate in response. The identification of additional *M. hapla*-resistant perennial ornamentals will aid in nematode management in nurseries and landscapes.

(1211)

Lamont, G. P., O. C. MA, et al. (1985). An

evaluation of pre-emergent herbicides for container-grown ornamental plants. *Scientia Horticulturae* 26(3): 241-251.

Two applications of 5 herbicides were evaluated during spring and summer for weed control and phytotoxicity on 25 species of trees, shrubs and herbaceous perennials. Oxyfluorfen applied at 1.25, 2.5 and 5.0 kg ha⁻¹ controlled grass and broad-leaved weeds for 8 weeks after the first application, and the 2 higher rates controlled all weeds for 12 weeks after the second application. Oxadiazon at 2.0, 4.0 and 8.0 kg ha⁻¹ controlled all weeds for 8 weeks after the first application, but only the highest rate was effective 12 weeks after the second application. Napropamide at 5.0, 10.0 and 20.0 kg ha⁻¹ controlled grasses for up to 12 weeks, but only controlled broad-leaved weeds at the 2 higher rates for 8 weeks after the first application and failed to control them after the second application. Alachlor at 4.0, 8.0 and 16.0 kg ha⁻¹ and oryzalin + trifluralin at 0.5, 1.0 and 2.0 kg ha⁻¹ controlled grasses for 8 weeks after the first application. These herbicides at the highest rate also controlled broad-leaved weeds for 8 weeks after the first application. However, alachlor and oryzalin + trifluralin failed to control any weeds after the second application.

Competition from weeds reduced the shoot dry weight of unweeded control pots by 20% compared with hand-weeded control pots. None of the herbicides produced visible damage in any plants. However, oxyfluorfen inhibited the growth of *Photinia* and *Coleonema*, alachlor inhibited the growth of *Photinia*, *Eriostemon*, *azalea* cv. *Splendens*, *Lavandula* and *Coleonema*, Oryzalin + trifluralin inhibited the growth of *Bauhinia*, and napropamide and oxadiazon inhibited the growth of *Coleonema*.

(1215)

Lanphear, F. O. (1971). Urban vegetation: values and stresses. *HortScience* 6(4): 332-334. Discussed in relation to the aesthetic and functional value of ornamental annual and perennial herbaceous plants, trees and shrubs. Increasing urban problems in regards to people and plants suggest consideration of a new emphasis in urban horticulture. This article is based on a talk presented by F.A. Lanphear at a symposium entitled "Urban Ecology Today" at the AAAS meetings in Chicago, Illinois in December 1970.

(1164)

Lehtila, K. and K. Syrjanen (1995). Positive effects of pollination on subsequent size, reproduction,

and survival of *Primula veris*. Ecology 76(4): 1084-1098.

Three experiments were conducted in which additional hand pollination, flower removal and leaf removal treatments were applied in various combinations to *Primula veris*, a perennial spring-flowering rosette species. The purpose of the study was to determine whether seed set of *Primula veris* was limited by pollen availability or by other resources, and whether there were measurable costs of reproduction. Hand pollination significantly increased current seed set in only one of the three experiments. It also increased the next-year fruiting probability in that first experiment. In the second experiment, hand pollination did not significantly affect current seed set, but nevertheless enhanced leaf growth was observed in the treatment year and the following 2 years, and increased flowering and fruiting frequency, and survival in the following 2 years. In the third experiment, after hand pollination a higher net photosynthetic capacity of the leaves was noted along with increased leaf growth in the treatment year and a higher flowering probability in the following year. The positive effect of hand pollination was more obvious when the leaves of the plants were removed at the beginning of the experiment. However, the treatment in which all the flowers were removed had effects on subsequent performance similar to those of the hand pollination treatment, suggesting trade-offs. No costs associated with reproduction after supplementary hand pollination were observed; on the contrary, hand pollination resulted in increased survival, size and reproduction of the plants in the subsequent years.

(1171)

Levine, H. G. and A. D. Krikorian (1992). Shoot growth in aseptically cultivated daylily and haplopappus plantlets after a 5-day spaceflight. *Physiologia Plantarum* 86(3): 349-359. Plantlets of daylily (*Hemerocallis* cv. Autumn Blaze), regenerated from cell suspensions, and 4 clonal populations of *Haplopappus gracilis* were aseptically cultivated aboard the Shuttle 'Discovery' during a 5-day mission within NASA's Plant Growth Unit (PGU) apparatus. Daylily was selected as a representative herbaceous perennial monocotyledon and *H. gracilis* as an annual dicotyledon. The latter included 4 strains with different physiological and morphological characteristics: 2 aseptic seedling clones and 2 tissue culture-derived lines. Mean daily growth rates for the primary shoots of all plantlets averaged 4.13 mm/day (s.d. = 2.20) for the flight

experiment and 4.68 mm/day (s.d. = 2.59) for the ground control. Comparable growth rates calculated by summing both the primary and secondary shoots were 5.94 mm/day (s.d. = 2.89) for the flight experiment and 6.38 mm/day (s.d. = 3.71) for the control. Statistically significant differences existed between: (1) flight vs. control primary shoot growth; (2) the different populations (daylily gained more shoot material than *H. gracilis*, and the *H. gracilis* seedling clones outperformed the tissue culture-derived *H. gracilis* lines), and (3) the individual Plant Growth Chambers contained within the PGU. The data suggested that some spaceflight-associated factor(s) increased the tendency for primary shoot apices to senesce, resulting in the release of apical dominance and the emergence of axillary branches. In addition to spaceflight-associated factors, the physiologically diverse nature of the experimental material, as well as environmental heterogeneities within the culture apparatus, contributed to the variation in growth results.

(1223)

Lindgren, D. T. (1990). 'Prairie Snow' penstemon. *HortScience* 25(4): 489.

Prairie Snow is a white-flowered, seed-propagated bulk population of *Penstemon grandiflorus* selected for landscape use and roadside plantings. Its origin, description and propagation are briefly mentioned. This cultivar is considered a short-lived perennial surviving 3-4 years. It flowers for about 3 weeks from late May.

(1219)

Lindgren, D. T. (1984). 'Husker Red' penstemon. *HortScience* 19(3): 459.

The new cv. is a white flowered red-foliage (stems and leaves) selection of *Penstemon digitalis*. It has the basic characteristics of *P. digitalis* except for the red foliage and produces, on average, 24 flower stalks/plant. Flowering starts on 15-20 June and continues for 15-20 days. Propagation is best by division or cuttings.

(1218)

Lindgren, D. T. (1984). 'Schooley's Yellow' penstemon. *HortScience* 19(3): 458.

The new cv. is a yellow-flowered selection of *Penstemon barbatus*. It has the basic *P. barbatus* characteristics, except for the yellow blooms and above average number of flower stalks/plant (15-25). Flowering starts in early June and continues for 2-3 weeks. When the flower stalks were removed immediately after flowering the plant flowered again in late summer. Schooley's Yellow

tends to grow as a short-lived perennial and division of the clump or re-starting from cuttings after 3 years is recommended.

(1195)

Lockhart, B. E. and J. A. Westendorp (1998). Anemone - an additional perennial ornamental host of tobacco rattle virus in the US. *Plant Disease* 82(6): 712.

The occurrence of tobacco rattle tobavirus (TRV) in anemone (*Anemone X hybrida* cv. *Honorine Jobert*) with leaf symptoms consisting of chlorotic blotches, chlorotic line patterns and distortion is reported. Characteristic tobavirus-like particles with modal lengths of 50, 80, 130 and 180 nm were observed in partially purified extracts of symptomatic but not of asymptomatic plants. These particles reacted specifically with antibodies to TRV and pea early browning tobaviruses in immunoelectron microscopic (IEM) assays, produced typical TRV-induced symptoms in *Nicotiana benthamiana* and *N. clevelandii*, in which similar particles were detected by IEM, but, like other TRV isolates, did not infect pea. No other virus-like particles were observed in partially purified extracts of symptomatic anemone plants.

(760)

Lumis, G., P. Purvis, et al. (1996). Cover crops for nursery tree production. *Landscape Trades*(September): 11 - 13, 42. Permanent cover crops of perennial grasses and/or legumes are often used in horticultural crop production. Cover crops grown between rows of orchard or nursery trees help to reduce soil erosion (3,4), water and sediment run-off (3), weeds and herbicide inputs (4) and soil temperature (8). Also, cover crops increase soil organic matter (4,8), soil moisture infiltration and retention (5), and may increase crop plant survival (7) as well as crop nutrient content (10). Cover crops also enable equipment to move more easily during moist spring and fall digging. Despite these potential benefits, growing permanent cover crops between rows of nursery stock is not a common practice. Possible concerns with cover crops are competition for water and nutrients as well as their being a host for rodents and crop damaging insects.

The purpose of this study was to determine the effect of three permanent cover crops on the growth of several nursery tree species. Also, we examined the influence of the cover crops on soil pH and organic matter.

(1089)

Mackay, W. A., T. D. Davis, et al. (1996). Factors influencing seed germination of *Lupinus perennis*. *Journal of Environmental Horticulture* 14(4): 167-169.

Seeds of *Lupinus perennis* (perennial lupine) were subjected to a variety of scarification and temperature treatments. Without scarification, <15% germination was observed within 1 week. Germination increased quadratically as the duration of acid scarification time increased. After 15 min of scarification, nearly 90% of the seeds germinated and nearly 100% germination was obtained after 45 min of scarification. Nicking the seed coats with a razor blade resulted in 100% germination. In contrast, soaking seeds in water at 22°C for 24 h failed to enhance germination. Total germination of scarified seeds was >80% between 21 and 29° within 54 h. The most rapid germination occurred at 24 to 29°. At 32°, total germination was reduced to approximately 60%. At temperatures >35°, total germination was reduced to less than 4%. Germination occurred equally well in the light or dark.

(1174)

Mallika, V. K., K. V. Peter, et al. (1988). Interspecific hybrid between *Amaranthus spinosus* (section *Amaranthus*) and *A. viridis* (section *Blitopsis*). *Current Science* 57(21): 1185-1188. The first successful hybridization between the wild species *A. spinosus* and *A. viridis* (both *n* = 17) is reported. The hybrid, unlike the parents, is short and robust with perennial growth habit. Most of the male flowers produced were sterile but many of the anthers formed in some flowers dried off without dehiscence. Meiosis was regular in the parents with 17 bivalents forming at metaphase I. The hybrid formed, on average, 14.4 bivalents and 5.3 univalents, and failure of the univalents to orientate produced abnormalities in later stages. The hybrid showed 62.6% pollen sterility. These results do not support the taxonomic separation of the 2 parent species since genomic similarities exist between them.

(1148)

Maqbool, M. and A. C. Cameron (1994). Regrowth performance of field-grown herbaceous perennials following bare-root storage between -10 and +5°C. *HortScience* 29(9): 1039-1041. Many herbaceous perennials are field-grown, harvested in autumn and stored bare-rooted for up to several months until marketing in winter or spring. Field-grown plants of *Alcea rosea*, *Asparagus officinalis*, *Coreopsis grandiflora* cv.

Sunray, *Dicentra spectabilis*, *Gaillardia X grandiflora* cv. Baby Cole, *Lupinus polyphyllus* (Russell hybrids) and *Phlox subulata* cv. Emerald Pink, harvested as bare-root crowns in late autumn, were packaged in polyethylene-lined crates and stored for 6 months. There were no significant differences in the regrowth performance of any of the perennials following storage at 0 or -2°C. The amounts of surface covered by fungal hyphae (surface mould) increased more than 2-fold between 4 and 6 months of storage at 0 or -2°C on all species. *D. spectabilis* and *A. rosea* were most susceptible to mould growth during storage. *A. rosea* and *C. grandiflora* stored poorly at all storage temperatures. In a second experiment, the regrowth performance of *Artemisia schmidtiana* cv. Silver Mound, *Asclepias tuberosa*, *Aster novae-angliae*, *Centranthus ruber*, *Chrysanthemum X superbum* [*Leucanthemum superbum*], *Dicentra eximia*, *Dicentra spectabilis*, *Geum quellon* [*G. quellyon*] cv. Mrs. Bradshaw, *Hosta* cv. Honeybells and *Lupinus polyphyllus* was tested following 6 months of storage at temperatures between -10 and +5°C. Regrowth performance was generally similar at -2, 0 and 5°C for most species. The results indicated, however, that *C. ruber* and *C. superbum* should not be stored at temperatures of < -2°C. Sufficient etiolated growth developed for most species when stored at > 2°C to cause problems during shipping, handling and potting. In general, mould growth on crowns during storage did not reduce regrowth performance of the species tested.

(1176)

Marino, P. C., R. M. Eisenberg, et al. (1997). Influence of sunlight and soil nutrients on clonal growth and sexual reproduction of the understory perennial herb *Sanguinaria canadensis* L. *Journal of the Torrey Botanical Society* 124(3): 219-227. Permanent plots of the rhizomatous understory perennial herb *Sanguinaria canadensis* were established in a high-light site with large, many-leaved plants and a low-light site with small, few-leaved plants. Within these plots, a reciprocal transplant study was performed to separate local evolutionary differentiation from environmentally determined differentiation. Also, half the plots in each site were fertilized to explore effects of soil fertility on vegetative growth and sexual reproduction. Plants from a third high-light site were used in a potting study to explore combined influences of elevated sunlight and fertilization on vegetative growth and sexual reproduction. Fertilization results in plants with proportionally fewer small and more large leaves in high-light

permanent plots and had no effect on plants growing in low-light permanent plots. Fertilization increased leaf number and total leaf area, but had no influence on seed production in the potting and reciprocal transplant studies. Unshaded plants had significantly more leaves and greater total leaf area in the potting study. Also, in the high-light site of the reciprocal transplant study, both fertilized and unfertilized plants (especially fertilized plants originating from the high-light site) had more leaves and a higher total area per plant than plants growing in the low-light site. Light intensity did not influence seed production in the potting study; however, more seeds were produced on plants growing in the high-light site than in the low-light site. Mortality was high for plants transplanted into the low-light site and for fertilized plants growing in shade in the common garden study. Clonal growth as measured by leaf size and leaf number in *S. canadensis* is highly flexible and responds vigorously to increased sunlight and to fertilization when under high-light conditions. In contrast, sexual reproduction exhibits relatively little flexibility. Local populations of *S. canadensis* responded rapidly to increases in light and nutrients associated with disturbance through increased clonal growth. This rapid response to environmental variability may partly explain the patchy spatial distribution of *S. canadensis* populations.

(1126)

Matsuzawa, Y. and K. Saito (1974). Variation of chromosome numbers and restoration of plantlet in callus tissue derived from the stem of summer perennial phlox, *Phlox paniculata* L. *Bulletin of the College of Agriculture, Utsunomiya University* 9(1): 7-14.

Stem segments cultured on Murashige and Skoog's basal medium alone or supplemented with 2,4-D or kinetin produced vigorous callus growth. Tissues cultured on the medium alone or with kinetin formed many protuberances and some of them later differentiated shoot systems. Where 2,4-D was present the tissues were relatively smooth with uniform cell populations and no organogenesis occurred. Although tetraploid cells were present where kinetin or kinetin plus 2,4-D had been added all plantlets obtained proved to be diploid.

(1151)

May, M. (1998). Victorian visions. *Garden London* 123(5): 356-361.

Violas (*Viola*) and *violettas* are perennial garden flowers with an extensive colour range and long flowering season. The cultural requirements,

propagation (cuttings, layering and dividing), pests and diseases, and recommended cultivars in the UK are presented.

(1147)

McGourty, F., Jr. and M. E. B. Joyner (1978). Perennials and their uses. *Plants and Gardens* 34(3): 1-88.

This issue of the journal contains many short articles by different authors on the selection, propagation and cultural requirements of ornamental herbaceous and rhizomatous perennials for different regions of the USA.

(415)

Meade, J. A. (1991). Managing perennial weeds in the nursery. FS Cooperative Extension Service Cook College(565): 2.

(1130)

Metzger, J. (1994). *Sedum aytacianum* (Crassulaceae), a new species from Turkey. *Cactus and Succulent Journal* 66(6): 259-261.

This small, herbaceous perennial is a member of section Sedum and is known only from the vicinity of Macka, 30 km from Trabzon in N.E. Anatolia. It is described and distinguished from the closely related S. hispanicum (which is upright in growth and generally annual). In cultivation, it flowers at the end of June.

(1154)

Meyer, S. E. and S. G. Kitchen (1992). Cyclic seed dormancy in the short-lived perennial *Penstemon palmeri*. *Journal of Ecology* Oxford 80(1): 115-122.

Penstemon palmeri is a short-lived perennial herb that occupies early-successional habitats at mid-altitude in the semi-arid south-western USA. Laboratory germination experiments with seeds from 9 populations showed that most seeds were non-dormant at autumn temperatures (15°C), but a majority required light for germination. Moist chilling at winter temperatures (1°) for 4 weeks induced secondary dormancy in about half the seeds, whilst moist incubation at superoptimal summer temperatures (30°) for 2 weeks removed most primary and chilling-induced secondary dormancy, prevented the induction of dormancy by chilling, and reduced the proportion of light-requiring seeds. The effect of 1° and 30° treatments persisted or were increased through drying. A 2-year field retrieval experiment with seeds from 3 populations in Utah showed that dormancy induction during winter and release from dormancy during summer functioned as

predicted from laboratory experiments to confine germination to periods during autumn or early spring and to permit year-to-year persistence of the seed bank. Cyclic dormancy patterns demonstrated for P. palmeri are similar to those described for facultative winter annual weeds. However, because chilling causes the seed population to diverge into spring-germinable and spring-dormant fractions, its seed bank can persist from year to year without burial. There were no clear habitat-correlated differences in germination patterns between populations, and populations from contrasting habitats showed similar and appropriate field responses. This suggests that the species is a generalist in terms of germination pattern.

(1157)

Mitchell, R. J. and R. G. Shaw (1993). Heritability of floral traits for the perennial wild flower *Penstemon centranthifolius* (Scrophulariaceae): clones and crosses. *Heredity* 71(2): 185-192. *Floral and reproductive traits frequently influence pollinator behaviour and plant reproductive success and are therefore thought to be under selection. However, for wild plant populations there is little information on the amount of genetic variation for such traits. Broad- and narrow-sense heritability of floral and reproductive traits were estimated for two populations of the perennial wildflower Penstemon centranthifolius, using a paternal half-sib crossing design in one case, and clonal propagation of ramets from different genets in the other. In both designs, most traits were significantly heritable, including nectar production, corolla length and width, inflorescence length and total flower production. Flowering date was significantly heritable for the crosses, but not for the clones, while nectar sugar concentration was not significantly heritable in either design. Genetic correlations were in some cases strong, and in some cases differed greatly from the corresponding phenotypic correlations. These results indicate that P. centranthifolius harbours a large reservoir of genetic variance which could support an evolutionary response to phenotypic selection.*

(1212)

Mitchell, W. H., C. J. Molnar, et al. (1994). Using composts to grow wildflower sod. *BioCycle* 35(2): 62-63.

Five municipal waste composts and ProGrow (a peat + perlite potting compost, used as the control) were compared for raising turf composed of native annual and perennial wild flower seedlings. Such

turf is used to re-establish roadside plantings and to stabilize soil on these sites as an alternative to traditional grass mixtures. In the first of 2 trials, 2 types of plastic netting placed on the base of the plastic seed tray to increase sod strength were compared for effect with unamended composts. Seeds of a Northern wildflower mixture (annuals alone or mixed with perennials) were sown at 0.5 lb/1000 ft² on a one-inch-deep layer of compost and watered daily. The sod was examined at intervals for stand density, tensile strength and market quality. Seeds germinated earliest in MSW (composted municipal solid waste) and the control compost. After 10 weeks of growth, the MSW compost gave clearly superior results, whereas stand density was lowest in the control compost; the latter appeared to be nutrient-deficient although a top dressing of NPK fertilizer had been applied to both these media. Sod tensile strength was significantly improved by the incorporation of plastic netting with 0.75-inch apertures or a textile fibre netting. In the absence of either fabric, the control compost produced a stronger sod than other media, but in terms of market quality any sod grown without netting was not generally acceptable. Sod strength was generally higher for annual species than for a mixture of annuals and perennials; the widest range of species was produced in Earthlife (a sludge + wood chip compost) and MSW. In the second trial, netting was placed on the base of half the trays, which were filled with the same composts as before. Half the trays in each group were drenched with 2 inches of water, before a blend of annual and perennial species was sown at 0.5 lb/1000 ft². Drenching did not affect the average plant density significantly 2 weeks after sowing, but there was a significant interaction between watering treatments and growing media. This was most marked for 2 composts that contained high levels of soluble salts, viz. Earthlife and Fairgrow (a combination of MSW and dewatered sludge). Six weeks after sowing, the drenching effects had largely disappeared and the Earthlife compost was superior in terms of plant density and growth. The netting appeared to contribute to differences noted in plant density, the effect being related to the compost used.

(1099)

Morgan, S. (1983). Choice of containers for nursery stock. *Grower* 99(25): 14-15. Findings are presented of a survey of (1) eight UK nurseries producing herbaceous and woody ornamentals in containers, and (2) 100 nursery customers including garden centres, local

authorities and landscape contractors. Preferences for rigid or soft plastic pots were related to cost, ease of storage and handling and plant quality. Pot size used ranged from 0.3 to >10 litre capacity. The majority of the nurseries used polybags for 3-, 4-, 5- and 6-litre containers and rigid pots for the smaller sizes. Six used a combination of both types over the range 1-4 litre. Handling of empty rigid pots was more time consuming, but potting was quicker than with polybags and thus more plants could be potted earlier in the growing season. However, this increase in throughput required more labour and transport from the potting machine to the standing beds. When plants were transported for sale, fewer rigid than soft pots could be fitted into a unit load but the increase in cost/pot was low (<6%). About half of all the customers preferred rigid to soft pots for ease of handling and presentation, although soft pots were generally used for roses and herbaceous perennials and were less likely to dry out than rigid pots. Almost all customers could not detect any difference in plant quality between those received in rigid and in soft pots.

(1131)

Morita, O., H. Ehara, et al. (1995). Role of hypocotyl hairs in seedling-establishment of wildflowers for landscaping. *Grassland Science* 41(1): 71-73.

Seeds of 19 annual and perennial "wild flower" species (ornamental plants introduced from Europe and the Americas) were sown on the soil surface in containers and allowed to germinate for 7 days at 25°C and 100% RH. Twelve of the 19 species had hypocotyl hairs, but their occurrence appeared to be independent of taxonomic classification. Species with a 1000-seed weight of <1 g did have hypocotyl hairs, while those with larger seeds did not. Immediately after their appearance, hypocotyl hairs adhered to the soil surface in a ring and then the taproot emerged through the ring. In most cases, the taproot tip of seedlings with hypocotyl hairs could penetrate the soil immediately, rather than growing above the soil surface briefly (delayed penetration), but the percentages of seedlings which showed the 2 types of behaviour varied between species. In *Papaver rhoeas* (hypocotyl hairs present), the percentage of seedlings with immediate soil penetration by the taproot increased from 0 to 51% when soil hardness was reduced from 12 to 1.5 mm. However, in *Mirabilis jalapa* (no hypocotyl hairs), taproot penetration of the soil was delayed in all seedlings at both soil hardnesses. It was concluded that hypocotyl hairs are important for the seedling

establishment of surface-sown "wild flower" seeds.

(370)

Neal, J. C. and A. F. Senesac (1991). Preemergent herbicide safety in container-grown ornamental grasses. *HortScience* 26(2): 157-159.
Preemergent herbicide phytotoxicity was evaluated for six species of container-grown ornamental grasses: beach grass (*Ammophila breviligulata* Fern.), pampas grass [*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.], tufted hair grass [*Deschampsia caespitosa* (L.) Beauvois.], blue fescue [*Festuca ovina* cv. *glauca* (Lam.) W.D.J. Koch], fountain grass [*Pennisetum setaceum* (Forssk.) Chiov.], and ribbon grass (*Phalaris arundinacea* cv. *picta* L.). Herbicides included isoxaben, metolachlor, MON 15151, napropamide, oryzalin, oxadiazon, pendimethalin, prodiamine, and trifluralin; the granular combination products of benefin plus trifluralin; and oxyfluorfen plus pendimethalin. Metolachlor, granular or spray, and oryzalin severely injured all species tested, except beachgrass, which was not injured by metolachlor granule. Napropamide injured pampas grass, fountain grass, blue fescue, and tufted hair grass, but was safe on ribbon grass and beach grass. Pendimethalin, prodiamine, trifluralin, MON 15151, isoxaben, oxyfluorfen plus pendimethalin, and benefin plus trifluralin were safe on all six species.

(1179)

Nieto Feliner, G. (1991). Breeding systems and related floral traits in several *Erysimum* (Cruciferae). *Canadian Journal of Botany* 69(11): 2515-2521.
The breeding system of 13 populations belonging to eight species of *Erysimum* (Cruciferae) was studied and its association with the life-span of the plants is discussed. To assess the breeding system of each population, greenhouse tests for apomixis, self-compatibility, and self-pollination were carried out, morphological characters like petal size and anther length were measured and pollen to ovule ratios were computed. The evidence gathered supports the selfing behaviour of the three annuals, *E. cheiranthoides*, *E. incanum*, *E. repandum*, and the outcrossing behaviour of the perennials *E. linifolium*, *E. asperum* and *E. menziesii*. Among those two groups, *E. inconspicuum* and *E. suffruticosum* apparently occupy an intermediate position, although the former tends more towards autogamy, whereas the latter tends towards allogamy. The importance of the breeding system data in the systematics of this genus, particularly in studying the apparent links

between the Mediterranean annuals and the temperate *E. hieracifolium* group, is briefly discussed.

(1190)

Nyman, Y. (1993). The pollen-collecting hairs of *Campanula* (Campanulaceae). II. Function and adaptive significance in relation to pollination. *American Journal of Botany* 80(12): 1437-1443.
A peculiar and often discussed feature in the genus *Campanula* is the presence and function of the pollen-collecting hairs (PCHs), covering the style and the dorsal surface of the stigmatic lobes on the pistil. The hairs sweep up the pollen as the anthers dehisce, and this 'stylar brush' serves as a secondary pollen presentation mechanism, facilitating the transfer of pollen from the flower to visiting insects. The adaptive significance of the hairs in relation to pollination has been variously interpreted by several authors during the past two centuries, but a satisfactory explanation for the floral mechanism is still lacking. Comparisons were made among species with various degrees of protandry and different mating systems, and between annuals and perennials. The results clearly show that the hairs serve not only as pollen-collectors, but also as an important and efficient mechanism controlling stigma spreading and promoting cross-pollination. A tactile stimulation of the hairs causes a shortening of the length of the male phase and accelerates stigma maturation. The more frequently the hairs are treated, the shorter the male phase. Similar trends were found in all species regardless of differences in the degree of protandry, life span, or mating system. Geographically well-separated populations in two species showed differences in length of the male phase, depending on mating system and/or weather conditions. The effects of the method used in this study on the PCHs is compared with those of pollinator activity. The consequences of the retraction of the hairs with respect to self-pollination are briefly discussed.

(1143)

Nyman, Y. (1992). Pollination mechanisms in six *Campanula* species (Campanulaceae). *Plant Systematics and Evolution* 181(1-2): 97-108.
Pollination mechanisms within the genus *Campanula* were studied. Tests were undertaken to examine whether in vitro culture of pollen grains can serve as a useful tool for understanding the self- and cross-pollination mechanisms among species. Characteristics of pollen germination were interpreted in relation to mating system and floral biology. Four annual species (*C. kremeri*, *C.*

dichotoma, *C. afra*, *C. lusitanica*), and two perennial species (*C. rotundifolia* and *C. persicifolia*) were investigated. In the annual species pollen germinability is controlled by (1) the age of pollen and/or (2) in what position pollen is deposited around the style. Correlations were found between pollen germinability and mating systems in three of the four annual species. No correlations were found either between germinability and age of pollen or position on the style in the perennial species. Pollen germinability reached its maximum in the middle of the male phase in all species, except for *C. dichotoma*, which had a decreasing germinability throughout anthesis. The germinability was lowest at the time of stigma receptivity for all species except for *C. persicifolia*, where the stigma did not develop as long as pollen remained on the style. The pollen collecting hairs and pollen removal have been found to play an important role controlling the stigma development, thus affecting self-pollination. This was especially pronounced in *C. persicifolia*.

(1168)

O'Brien, T. and A. V. Barker (1995). Evaluation of fresh and year-old solid waste composts for production of wildflower and grass sods on plastic. *Compost Science and Utilization* 3(4): 69-77. One-year-old and fresh composts of mixed municipal solid wastes (MSW), agricultural wastes (chicken manure and cranberry pomace) and autumn leaves were evaluated for their capacity to support the production of *Lolium perenne* cv. Pennfine or mixed wild flower swards (species such as *Coreopsis tinctoria*, *Eschscholzia californica*, *Cosmos* sp., *Silene armeria*, *Hesperis matronalis* and *Cheiranthus* [*Erysimum*] *allionii*) at the University of Massachusetts, Amherst. Composts were laid in 5-cm-thick layers on plastic in outdoor plots, and germination, stand establishment, biomass production and flowering responses were assessed for each medium. Seed germination and stand establishment were sensitive to limiting factors present in the fresh composts of mixed MSW or autumn leaves. Subsequent plant growth was reduced in these composts largely due to the poor establishment of stands, the limiting factors being identified as excessive ammonium in the fresh MSW compost and inadequate total N in the leaf compost. Aging of the composts increased their value in sward production by lowering the concentrations of ammonium in the MSW compost and by increasing the concentration of N in the leaf compost. Agricultural compost was N-rich but low in ammonium, and aging of this compost had a less

significant effect on plant growth than with the other composts. The flowering of annual wild flowers in the first season and early flowering biennial and perennial wild flowers in the second season was greater using the mixed MSW or agricultural compost compared with leaf compost. Late flowering species were unaffected by the source of compost in the second season. It is suggested that a fully mature compost is required for production of high quality swards.

(1124)

Olsen, S., D. Amundsen, et al. (1999). The Utah Botanical Gardens: an educational resource for the university and the community. *HortTechnology* 9(4): 562-565.

University students have been involved with the Utah Botanical Gardens (UBG) since their inception in 1954 as part of the Utah State University (USU) Utah Agricultural Experiment Station (UAES). Students and professors travel from USU to visit UBG, conduct class tours, and participate in research projects. Students also work at UBG as summer interns, and in 1986, USU began offering off-campus horticulture classes for credit at UBG. Today, 20 different classes are taught at UBG or nearby sites. These classes are part of the USU Applied Ornamental Horticulture degree program and can also be used to qualify as a Certified Nursery Professional by the Utah Nursery and Landscape Association.

(1149)

Park, K., J. Chung, et al. (1998). Spatial genetic structure among Korean populations of *Hemerocallis thunbergii* (Liliaceae). *Journal of Japanese Botany* 73(3): 137-142. The spatial distribution of genotypes were investigated among 10 Korean populations of *Hemerocallis thunbergii*, a herbaceous perennial native to East Asia, using spatial autocorrelation analysis of enzyme polymorphism. A weak genetic structuring exists among the Korean populations. Only 10% (22 of 225) of Moran's *I* values for three interpopulational distance classes was significantly different from expected values ($E[I] = -0.111$). No distinct trend with respect to the distance classes was detected (average Moran's *I* values were -0.09, -0.12, and -0.11). These results may in part result from long distance dispersal by pollinators such as moths and butterflies and then the secondary movement of seeds into adjacent continuously distributed populations in the southwestern Korean Peninsula.

(1246)

Pellett, D. J. (1993). Hosta. *Am Nurseryman* 177(6): 53-58, 60-61.

(981)

Pellett, H. M. and J. V. Carter (1981). Effect of nutritional factors on cold hardiness of plants. *Horticultural Reviews* 3: 144 - 171.

A review and discussion on the evaluation of research relating nutrition to plant cold hardiness, the relationship of nutrition to the mode of action of the cold acclimatization process, the influence of nutrient levels on different types of cold injury, and the relationship of nutrition to cold hardiness of specific temperate woody and herbaceous plants and sub-tropical plants.

(999)

Pellett, N. and D. Heleba (1994). Comparison of chopped newspaper with microfoam for winter protection of container-grown nursery stock. *HortTechnology* 4(1): 55-57.

Container-grown Juniperus horizontalis cv. Prince of Wales, Physostegia virginiana cv. Crown of Snow, Gaillardia grandiflora cv. Goblin and Daphne burkwoodii cv. Carol Mackie plants were covered in blocks on 21 Nov. 1991 and the covers removed on 10 Apr. 1992. For the cover treatments, a double layer of 0.64-cm-thick microfoam was compared with chopped newspaper at 3.5 or 7.0 kg/m² enclosed in white polyethylene sheeting or at 3.5 kg/m² enclosed in nylon netting. During Jan. and Feb., ambient temperatures sometimes fell to -18°C and lower. All coverings increased the temperature of the container medium during these periods and greatly increased the percentage of living plants (recorded in May) compared with uncovered controls. In D. burkwoodii, net-enclosed newspaper resulted in far fewer plants having vigorous shoot growth (3 or more shoots longer than 2 cm) in May than the other treatments (9 vs. 51-70% respectively). The percentage of G. grandiflora plants with vigorous shoot growth was higher with the microfoam covering than with the newspaper treatments (98 vs. 48-70% respectively), but all coverings provided equally good protection for J. horizontalis and P. virginiana.

(1072)

Perry, L. P. (1990). Overwintering container-grown herbaceous perennials in northern regions. *Journal of Environmental Horticulture* 8(3): 135-138.

In a 3-year study, survival was evaluated in 9 container-grown herbaceous perennials using various overwintering techniques. Covers were

applied in Nov.-Oct. and removed at different times between 1 Apr. and 2 May. Although species reacted individually to overwintering covers, those covers with white reflective surfaces (e.g. white polyethylene film) generally provided adequate protection. Straw, non-reflective Plantfoam (plastic) or no cover usually resulted in large plant losses. Container medium temperatures were 4-7°C higher than surrounding air temperatures; a sandwich of 30 cm deep fluffed oat straw between layers of white polyethylene provided the least temperature fluctuation in the medium (3° with an ambient fluctuation of 16°) and the greatest temperature moderation (1° with ambient -16°). Uncovering plants later than the first week in Apr. occasionally resulted in plant losses.

(1088)

Perry, L. P. and T. Herrick (1996). Freezing date and duration effects on regrowth of three species of container-grown herbaceous perennials. *Journal of Environmental Horticulture* 14(4): 214-216. *Seedlings of Aquilegia cv. McKana's Giant, Dianthus deltoides cv. Vampire and Lavandula angustifolia cv. Munstead Dwarf were transplanted from 400 cell-size plugs to 400-ml containers and grown in a greenhouse at day/night temperatures of 25°/20°C until 10 October 1995. At that time greenhouses were programmed for ambient outdoor temperatures, but maintained above 3°C at night. Plants were exposed in controlled programmable freezers to temperatures of -5, -8, -11 and -14° on 15 November 1995 and 1 January 1996. Plants were allowed to remain at each temperature for either 30 or 120 minutes. Plants were then returned to the greenhouse, and rated for survival and salability following 6 weeks of regrowth at 15°. The rating scale was subjective and ranged from 1 to 5 (1 = worst, 5 = best, 3 and above considered salable). Regrowth means of all 3 species declined as treatment temperatures decreased. Although freezing date had a significant influence on regrowth quality of Aquilegia and D. deltoides, only freezing duration influenced D. deltoides regrowth. Neither factor significantly influenced regrowth quality of L. angustifolia. Treatment temperature and its interaction with freezing date or duration was statistically significant for all 3 species. All plants remained marketable following exposure to -11°C.*

(1242)

Perry, L. P. and N. Rowan (1989). Research report. "Sandwich" cover works well in Zone 5. *American Nurseryman* 169(1): 155.

Five protective overwinter coverings were

compared for nursery plants of *Lavandula*, *Dianthus*, *Cheiranthus* and *Heuchera* [unspecified] growing on a windy field site in Vermont (USDA hardiness zone 5). They comprised: one layer of 4-mm gauge white polyethylene sheeting; one layer of Microfoam plastic with a polyethylene cover; one layer of Plantfoam plastic; 3 layers of Microfoam with a polyethylene cover; and 2 layers of polyethylene with straw 1 ft deep sandwiched between the layers. Plants without coverings served as controls. All cover treatments for *Heuchera* resulted in 100% salable plants in the following spring, the polyethylene + straw cover giving the best results. For *Cheiranthus*, the 3-layer Microfoam cover and the polyethylene + straw cover were best. With the other 2 species there were no statistically significant differences in survival rates between treatments. In the following winter, 19 species of herbaceous perennials were either protected with the polyethylene + straw cover or not covered. Fourteen species survived much better under the cover and were usually salable, while 4 showed no difference in survival rates; plants of *Rudbeckia hirta* var. *pulcherrima* survived and remained salable when uncovered but died under the cover.

(1186)

Pors, B. and P. A. Werner (1989). Individual flowering time in a goldenrod (*Solidago canadensis*): field experiment shows genotype more important than environment. *American Journal of Botany* 76(11): 1681-1688. Individual plants of a population of clonal perennial goldenrod are consistent in rank order of flowering time over years. To determine whether this consistency is due more to environmental variation among microsites of individual clones or due to genetic variation among clones, similar sized sections of rhizomes were transplanted to an experimental garden. Three years later transplants and the original plants were examined for their floral phenology. No soil moisture or plant height gradient was significantly correlated with the flowering time of transplants. Time of flowering of transplants was consistent among replicates of individual clones across the soil moisture gradient and regardless of transplant size or the height of surrounding vegetation. Flowering times of transplants were significantly and positively correlated with the flowering times of the original plants in the same year. It was concluded that differences in flowering time among clones within this population were largely determined by genetic variation, rather than by environmental factors.

(242)

Porter, W. C. (1996). Isoxaben and isoxaben combinations for weed control in container-grown herbaceous flowering perennials. *Journal of Environmental Horticulture* 14(1): 27-30. Gallery DF (isoxaben), Snapshot DF (isoxaben+oryzalin), and Snapshot TG (isoxaben+trifluralin) were applied to four species in 1991 and to nine species in 1992 of container-grown herbaceous flowering perennials to evaluate efficacy, phytotoxicity, and effect on plant growth. Surflan AS (oryzalin) and Treflan 5G (trifluralin) were used as standard herbicide checks. Gallery was applied at 0.56, 0.84, and 1.12 kg ai/ha (0.5, 0.75, and 1.0 lb ai/A). Snapshot DF and Snapshot TG were applied at 2.8, 4.2, and 5.6 kg ai/A (2.5, 3.75, and 5.0 lb ai/A). Coreopsis was not affected by any herbicide treatment either year. Painted daisy was injured by all treatments except Snapshot TG at 2.5 lb ai/A and Trflan. Gallery at 1.12 kg ai/ha (1.0 lb ai/A) and Snapshot DF at 5.6 kg ai/ha (5.0 lb ai/A), injured all species except coreopsis and hibiscus. Surflan injured gloriosa daisy (1991 only), chrysanthemum, hollyhock, hibiscus, and painted daisy. Snapshot TG applied at 5.6 kg ai/A (5.0 lb ai/A) injured hollyhock. Height of coreopsis, shasta daisy, gloriosa daisy, and columbine was not affected or only slightly reduced by any treatment. Hollyhock, hibiscus, painted daisy, and chrysanthemum were generally shorter in containers treated with Snapshot DF at 4.2 kg/ha or higher rates.

(661)

Powell, C. C. (1987). Disease control in the nursery : with special reference to woody and herbaceous perennials. Rev. [Columbus, Ohio?], Ohio Cooperative Extension Service, Ohio State University, [1987] 24 p. : col. ill. This publication discusses strategies for and steps involved in disease management in the nursery with emphasis on woody and herbaceous perennial ornamentals. It includes information on plant pathogens and the diseases they cause, soil fumigation, lists of common diseases of ornamentals in Ohio, pesticide recommendations, dilution and conversion tables and Ohio Poison Information Centers.

(1101)

Rabcewicz, J. (1995). Mechanical weed control by shallow cultivation with three vertical-axis rotary implements. *Journal of Fruit and Ornamental Plant Research* 3(3): 125-142. The efficiency of three rotary weeding implements (ring-shaped blade, spring tines and nylon brush)

intended for use in orchards were compared during one season on crop-free soil at Alnarp, Sweden. The purpose was to compare the weeding effect of shallow cultivation (2 to 4 cm depth). White mustard (*Sinapis alba*) was used as the annual weed test plant and creeping thistle (*Cirsium arvense*) was used as a test plant for perennial weeds. The best weed control of white mustard plants (93%) was achieved by using the ring blade equipment, while the nylon brush equipment achieved an efficiency of only 44%. The spring tines were not quite as efficient (88%) as the ring blade equipment. All three implements showed better results on 30-day-old plants than on 22-day-old plants. An increase of the rotating velocity of the tools significantly increased the weed control effect only for the spring tine implement. The introductory trials on creeping thistles showed that the nylon brush did not reduce the number of thistle shoots. Treatment repeated three times with the ring blade or spring tine equipment gave 83% and 45% reduction of shoots, respectively.

(225)

Rangeley, A. (1989). The suitability of plant tissue tests to indicate phosphorus deficiency in perennial ryegrass (*Lolium perenne* L.). Grass and Forage Science Journal 44(1): 91-95.
The phosphorous (P) status of perennial ryegrass was measured using three tissue tests. The results were compared with dry matter (DM) production from ryegrass, and levels of extractable soil P, taken from a fertilized non-calcareous gley in a field experiment. Large errors were associated with the test values but it was possible to separate P deficiency from luxury uptake with tissue tests for total P and inorganic P (Pi) in leaves. The latter test is simple and merits further investigation.

(1222)

Ray, D. T., A. E. Thompson, et al. (1988). Interspecific hybridization in *Cuphea*. HortScience 23(4): 751-753.
Eighteen interspecific hybrids from 8 different *Cuphea* species have been confirmed morphologically and cytologically. Seven hybrids from reciprocal crosses of various accessions of the herbaceous annual *C. procumbens* (n = 9) and the semiwoody perennial *C. llavea* (n = 9) exhibited a relatively high degree of fertility. Some hybrids have horticultural potential and are currently undergoing evaluation as new pot or bedding plants. Other hybrids that are sterile due to meiotic irregularities are listed. *C. leptopoda* X *C. lamimuligera* is of considerable interest,

because it is the first successful interspecific hybrid between species in different fatty acid groups. A relatively fertile amphidiploid of *C. leptopoda* X *C. lamimuligera* was induced by colchicine. Seeds were produced by self-pollination of the amphidiploid and attempts are being made to backcross the hybrid to the original parents.

(16)

Reed, D. W. and H. B. Tukey, Jr. (1987). Factors affecting foliar absorption of nutrients by selected landscape and herbaceous plants. Journal of Environmental Horticulture 5(2): 72-76.
Plants and solution properties affecting the absorption of double-labeled ^{86}Rb ^{33}P -phosphate, pH 7.2, by chrysanthemum leaves were studied. Leaf age did not affect absorption greatly. Optimum concentration for maximum total absorption and efficiency of absorption of both Rb and P without leaf burn was 20-30 mM Rb phosphate. Urea and several structurally related compounds (acetamide, propionamide and Rb acetate) decreased Rb and P absorption due to formation of salt deposits. Of 18 commercially available surfactants tested at 0.1%, only one significantly increased P absorption and all significantly decreased Rb absorption; many were phytotoxic. Of a variety of 20 different herbaceous ornamental and woody landscape species tested for their efficiency of absorption, P absorption ranged from 0.2 - 39% and Rb absorption ranged from 0.2 - 42%; surfactants generally increased the absorption of P and Rb for those species with waxy, pubescent or otherwise hard-to-wet leaves.

(1172)

Reveal, J. L., F. Caplow, et al. (1995). *Eriogonum codium* (Polygonaceae: Eriogonoideae), a new species from southcentral Washington. Rhodora 97(892): 350-356.
Eriogonum codium is formally described and illustrated. It is a low, matted, caespitose perennial with tomentose flowers and achenes, and was collected from the Hanford Nuclear Reservation, Benton Co., Washington, USA. It belongs to the same group of matted perennials in the subgenus *Eucycla* as *E. chrysops* but has a cymose-umbellate inflorescence similar to *E. cusickii*. The tomentose flowers and achenes readily distinguish the new species from all of its near relatives.

(1123)

Rodriguez, D., T. D. Davis, et al. (1993). Use of growth retardants in the production of container-grown *Salvia farinacea* X *longispicata* 'Indigo

Spires'. Plant Growth Regulator Society of America Quarterly 21(4): 180-189.

The herbaceous perennial cultivar *Indigo Spires*, recently released into commerce by the Huntington Botanical Garden in California, produces blue-purple flower spikes 20-30 cm long throughout the growing season. It shows potential as a landscape plant for southern climates. However, a problem encountered during nursery production of plants in containers is the very rapid vegetative growth; adequate watering is difficult to maintain and overgrown plants are easily toppled. With the aim of controlling vegetative growth, paclobutrazol, uniconazole and daminozide were applied at different rates using 4 application methods as follows: (1) soaking the basal 1-2 cm of unrooted cuttings in a solution for 24 h; (2) dipping the bases of unrooted cuttings in a solution for 3 s; (3) spraying the foliage of rooted cuttings immediately after planting in 0.5-litre containers; and (4) as for (3) with a second foliar spray 18 days later. Treatments (1), (3) and (4) were generally more effective than (2) and uniconazole was generally more effective than the other compounds in retarding shoot growth. The retardant activity of most treatments subsided after about 3 weeks. All the retardants tended to reduce the number of flower spikes/plant by 1-3 compared with the untreated controls. Nonetheless, even with the greatest growth checking treatments (uniconazole at 50 mg/litre as a 24-h basal soak or foliar spray) at least 5 spikes/plants were produced. Flower spike length was unaffected by most of the treatments and, except for uniconazole at 20 or 50 mg/litre applied as treatment (4), spike length was not reduced by more than 15%. These results indicate that control of excessive growth in this plant can be achieved in various ways.

(1073)

Roh, M. S., R. H. Lawson, et al. (1996). New floral crops in the United States. Progress in new crops: Indiana: 526-535.

Achievements during the last 10 years of a cooperative programme between the USDA and industry to develop new floral crops are presented. The report describes: the acquisition of new crops from Europe (Denmark, Netherlands and Austria), Japan, Thailand, Australia, New Zealand, South America and South Africa and their evaluation as potential new floral crops; progress with the development of specialty field-grown cut flower crops, annuals and perennials, and woody plants; and the development of new technologies to shorten the total cropping time of both new and old crops.

(605)

Rose, M. A. (1999). Nutrient use patterns in woody perennials: implications for increasing fertilizer efficiency in field-grown and landscape ornamentals. HortTechnology 9(4): 613-617. Timing nutrient application to periods of high nutrient demand could increase nutrient use efficiency and reduce the potential for fertilizer leaching or runoff. However, current recommendations for field nursery and landscape ornamentals (extension publications) suggest fertilizing in late fall and early spring despite research with perennial fruit crops that demonstrates low uptake potential during those times. Research is needed to resolve this apparent conflict. Application rates for woody ornamentals, established in the 1960s and 1970s, also need reexamination in the light of environmental concerns.

(669)

Rosecrance, R. C., R. S. Johnson, et al. (1998). The effect of timing of post-harvest foliar urea sprays on nitrogen absorption and partitioning in peach and nectarine trees. J hort sci biotech 73(6): 856-861.

The effects of timing of autumn foliar urea-N sprays on N absorption and partitioning were studied in mature peach cv. O'Henry and nectarine cv. Fantasia trees in orchards in California. A 10% 15N enriched urea solution was applied by either dipping individual shoots in 1995 or spraying whole tree canopies in 1996. Trees whose canopies were sprayed during the postharvest period with a 10% w:v urea solution in 1996 were excavated in the dormant season, and 15N contents and distribution were determined. Peach leaves rapidly absorbed urea-N irrespective of application date, and transport of urea-N to perennial tree parts occurred primarily within 4-7 days after application. Between 48 and 58% of the urea-N applied was recovered in abscised leaves and perennial organs. Leaves exported 60% of the foliar-applied urea-N following application in early autumn (September or October), but <50% export occurred when the fertilizer was applied shortly before leaf fall (November). Of the urea-N translocated, most was recovered in roots (38%) following application in September or October. Urea-N applied in November, however, remained largely in the current year wood (about 45%). Thus, export and translocation of foliar applied urea-N diminished during the final stages of leaf senescence. Foliar application of urea in September or October supplied the equivalent of

about 20% of crop N content, but only 14% (about 30% lower) when applied shortly before leaf senescence in November.

(1160)

Rossum, F. v., X. Vekemans, et al. (1997).

Allozyme variation in relation to ecotypic differentiation and population size in marginal populations of *Silene nutans*. *Heredity* 78(5): 552-560.

In Belgium, at the north-western margin of its geographical range, *Silene nutans* is a rare species, which has evolved a silicicolous (Si) and a calcicolous (Ca) ecotype, with contrasting morphometric traits. Genetic diversity and population genetic structure were examined for seven allozyme loci in 16 Si and 18 Ca populations (a total of 567 individuals). High genetic variation was found at both the ecotypic and population level, and no significant correlation was found between population size and any measure of genetic variation. The maintenance of high levels of genetic diversity in small, marginal populations might be explained by the perennial, long-lived life form and the outcrossing breeding system of the species. Additionally, low *FST*-values suggested that efficient gene flow was occurring within both ecotypes. Genetic distance measures and cluster analysis using UPGMA on the distance matrix revealed that the populations were differentiated according to their ecotypic property in two distinct gene pools. It is argued that the congruence of allozymic and morphometric differentiation between edaphic races is unusual for an outcrossing species. This finding, together with previous observations of isolating mechanisms between ecotypes, strongly suggests that incipient speciation is occurring within *Silene nutans* at the margin of its geographical range.

(62)

Roumkova, L. V. (1989). Effect of ethylene producing substances and cultar on some ornamental plants. *Acta Horticulturae*(251): 281-288.

Attempts were made to compare the influence of ethylene producing substances—ethrel, dextrel and kamposan with that of cultar in respect to chrysanthemum (*Chrysanthemum coreanum*, cultivar "Jantar"), phlox and dahlia. They were treated with ethrel, kamposan (1000 ppm), dextrel (5000 ppm) and cultar (25-50 ppm, trade name of paclobutrazol in USSR, ICI, England); as a surfactant tween-80 was applied. The plants were sprayed at the very beginning of vegetation when their height was 20-25 cm; the spraying was

performed three times with a week interval. The treatment with ethylene producing substances resulted in a 40% growth decrease as compared to controls at the beginning of development. Then the inhibitory effect stopped, so at the vegetation end the stem length was the same as with untreated plants. Ethrel and kamposan inhibited flower initiation very strongly (30-40 days). So, it is impossible to use ethylene producing substances for obtaining pot-bedding cultures of examined plants. The cultar treatment reduced stem height (50% compared to control plants). It delayed flowering for 3-5 days; a shorter period of inflorescence was observed after this substances application. Cultar continued its inhibitory action for 2 years after one year of treatment. Cultar is a very good substance for obtaining dwarfed form and therefore good for pot-bedding culture. As a result it is becoming possible to transplant the plants from field to greenhouse and vice versa.

(505)

Rowland, L. J., E. L. Ogden, et al. (1999). Use of blueberry to study genetic control of chilling requirement and cold hardiness in woody perennials. *HortScience* 34(7): 1185 - 1191.

We are using a combination of molecular, genetic, and physiological approaches to investigate genetic controls of chilling requirement and cold hardiness in blueberry (*Vaccinium* section *Cyanococcus*). In this paper, the term "cold hardiness" specifically refers to flower bud hardiness in the cold-acclimated state. The goals of our research are to:

- 1) construct a genetic linkage map of blueberry using diploid populations that segregate for chilling requirement and cold hardiness; 2) develop a better understanding of the modes of action of chilling requirement and cold hardiness genes, based on genetic analyses of gene action and quantitative trait loci (QTL) analyses, and tag genes controlling these traits. Concomitantly, we are trying to identify and isolate chilling/cold-responsive genes from blueberry and determine their relationship to dormancy and/or cold hardiness transitions. Here we describe the system (among blueberry populations) and the strategies used in our research, and discuss our progress in the research areas outlined above.

(1229)

Runkle, E. S., R. D. Heins, et al. (1998). Flowering of herbaceous perennials under various night interruption and cyclic lighting treatments. *HortScience* 33(4): 672-677.

Six long-day species of herbaceous perennials

were grown under 6 night-interruption (NI) photoperiod treatments to determine their relative effectiveness at inducing flowering. Photoperiods were 9-h natural days with NI provided by incandescent lamps during the middle of the dark period for the following durations: 0.5, 1, 2 or 4 h; 6 minutes on, 54 minutes off for 4 h (10% or 6/54 cyclic lighting); or 6 minutes on, 24 minutes off for 4 h (20% or 6/24 cyclic lighting). For 5 species, the experiment was repeated with more mature plants, and for *Rudbeckia fulgida* cv. Goldsturm, the experiment was repeated after cold treatment of 8 weeks at 5°C. The species generally showed a quantitative flowering response to the NI duration until a saturation duration was reached. As the length of the uninterrupted night break increased, flowering percentage, uniformity and number, and plant height increased, and time to flower decreased. Minimum saturation durations of NI were: 1 h for *Coreopsis grandiflora* cv. Early Sunrise and *Hibiscus moscheutos* cv. Disco Belle Mixed; 2 h for *Campamula carpatica* cv. Blue Clips and *Coreopsis verticillata* cv. Moonbeam; and 4 h for unchilled *R. fulgida* cv. Goldsturm. *Echinacea purpurea* cv. Bravado flowered similarly across all lighting treatments. The 6/24 cyclic lighting regime induced flowering comparable to that under a continual 4-h NI for 4 of the 6 species and the cold-treated *R. fulgida*. Flowering under the 6/54 regime was generally incomplete, nonuniform, and delayed compared with that under saturation duration treatments. Three of 5 species flowered earlier when more mature plants were placed under the NI treatments. Cold-treated *R. fulgida* flowered more rapidly than unchilled plants, and the saturation duration of NI decreased to 1 h.

(780)

Runkle, E. S., R. D. Heins, et al. (1999). Photoperiod and cold treatment regulate flowering of *Rudbeckia fulgida* 'Goldsturm'. *HortScience* 34(1): 55-58.

To determine the flowering requirements of *R. fulgida* cv. Goldsturm, plants were grown under 9-h photoperiods until maturity, then forced at 20°C under one of 7 photoperiods following 0 or 15 weeks at 5°C. Photoperiods consisted of a 9-h day that was extended with incandescent lamps to 10, 12, 13, 14, 16 or 24 h; an additional treatment was a 9-h day with a 4-h night interruption (NI). Non-cooled plants remained vegetative under photoperiods 13 h, and essentially all plants flowered under photoperiods 14 h or with a 4-h NI. Flowering percentages for cooled plants were 6, 56 or 84 under 10-, 12- or 13-hour daylengths, respectively, and 84 for the NI

treatment. Critical photoperiods were 14 or 13 h for non-cooled or cooled plants, respectively, and base photoperiods shifted from 13-14 h before cold treatment to 10-12 h following cold treatment. Within cold treatments, plants under photoperiods 14 hours or NI reached visible inflorescence and flowered at the same time and developed the same number of inflorescences. Fifteen weeks of cold hastened flowering by 25-30 days and reduced nodes developed before the first inflorescence by 28-37%. Cold treatment provided little or no improvement in other measured characteristics, such as flowering percentage and uniformity, flower number, plant height and vigour.

(845)

Ruter, J. M. (1996). Growth and flowering of three garden chrysanthemum cultivars produced in plastic or copper-impregnated fiber containers. *Journal of Environmental Horticulture* 16(4): 191-193.

A study was conducted with garden chrysanthemum cultivars Grenadine, Nicole and Tolima to evaluate growth and flowering in 3.6-litre fibre containers impregnated with cupric hydroxide compared with in 2.6-litre black plastic containers (controls). For all three cultivars, growth indices, shoot and root dry weights, and total biomass were greater in plants grown in fibre containers. Total number of flower buds per plant was 30, 32 and 53% higher in Grenadine, Nicole and Tolima, respectively, in fibre containers. Plants grown in cupric hydroxide-impregnated fibre containers had less root coverage at the container/substrate interface and no observable root circling in contrast to visible root circling in plants grown in black plastic containers. Foliar nutrient analysis on the cultivar Grenadine showed that K decreased and Fe and Cu increased when grown in cupric hydroxide-impregnated fibre containers. No visible nutrient abnormalities were observed.

(1132)

Sabre, M., K. D. Holl, et al. (1997). Potential use of wildflower species for landfill restoration in southwestern Virginia. *HortTechnology* 7(4): 383-387.

The aim of this study was to determine if wild flowers are a feasible alternative to the standard revegetation mixture (commonly non-native perennial forbs and grasses) for landfill sites in southwestern Virginia. A standard landfill revegetation mixture and a wild flower mixture were sown at a landfill in spring 1993 and were evaluated after one growing season. The number of

species established in the wild flower mixture subplots was greater than in the standard mixture subplots, whereas cover of the 2 mixtures did not differ significantly. *Rudbeckia hirta*, *Coreopsis lanceolata*, *C. tinctoria* and *Hesperis matronalis* thrived. *Lespedeza cuneata* was a confounding factor in determining cover estimates. The results suggest that several native and naturalized species have potential for landfill restoration.

(1177)

Sagisaka, S. and T. Araki (1983). Amino acid pools in perennial plants at the wintering stage and at the beginning of growth. *Plant and Cell Physiology* 24(3): 479-494.

Free amino acids in fruiting (e.g. apple), vegetable (asparagus), ornamental (e.g. rose) and cereal (winter wheat and winter rye) plants at the stages of wintering and the beginning of growth were analysed under natural conditions. From the major amino acid contents, the plants were separated into: those which accumulated arginine; those which accumulated proline; and those which accumulated arginine and proline. Comparison of the compositions at stages of wintering and the beginning of budding indicated that the increase in the proline level was related to the onset of growth. Synthesis of arginine and proline and translocation of proline possibly indicate that these substances play the role of filling-in materials in any particular tissue. For plants which require chilling temperatures for growth, the accumulation of arginine and proline was considered to be a normal event, since temporal changes in the major amino acids from arginine (and proline) through glutamate to asparagine plus aspartate were generally observed. Uncoupling between amino acid syntheses and the commencement of development was also observed in plants which were housed in a greenhouse during winter. A possible function of proline as a natural cryoprotectant is discussed.

(1057)

Samfield, D. M., J. M. Zajicek, et al. (1991). Rate and uniformity of herbaceous perennial seed germination and emergence as affected by priming. *Journal of the American Society for Horticultural Science* 116(1): 10-13.

Seeds of *Coreopsis lanceolata* and *Echinacea purpurea* (Texas wildflowers) were primed in aerated solutions of distilled water or 50 or 100 mM potassium phosphate (pH 7.0) at 16°C for 3, 6, 9 or 12 days. *Coreopsis* seeds primed in the 50 mM buffer germinated the most rapidly and uniformly, and, under stress conditions in the greenhouse,

resulted in a faster-growing, more-uniform crop than other treatments. Seeds primed in distilled water or the 50 mM buffer germinated faster and at higher rates at suboptimal temperatures (15°-20°) in the laboratory than non-primed seeds. Priming of *E. purpurea* seeds for 6 or 9 days in distilled water or in the 50 mM buffer resulted in faster, more-uniform germination than other treatments. Seedling emergence under stress conditions was improved by all priming regimes, with best emergence occurring in treatments that lasted >3 days. Priming also increased germination rates of *E. purpurea* at suboptimal temperatures in the laboratory.

(1095)

Sandbrink, J. M., L. Geurts, et al. (1989).

Chloroplast DNA variation in *Silene* section *Elisanthe* demonstrates *Silene noctiflora* L. is not properly classified. *Biochemical Systematics and Ecology* 17(7-8): 539-549.

Silene section *Elisanthe* comprises 6 well defined species. The species have many characteristics in common, but *S. noctiflora* deviates in several important respects. It is an annual hermaphrodite which cannot be crossed with the other easily hybridizing biennial or perennial species. The chloroplast DNA (ctDNA) of the 6 species was compared using RFLP analysis. Excluding *S. noctiflora*, the variation in ctDNA fragment patterns between all *Silene* section *Elisanthe* species was 2% or less. *S. noctiflora* had only about 52-53% bands in common with the other 5 species. It is concluded that the classification of *S. noctiflora* in *Silene* section *Elisanthe* is not justified.

(1158)

Schierenbeck, K. A., J. L. Hamrick, et al. (1995). Comparison of allozyme variability in a native and an introduced species of *Lonicera*. *Heredity* 75(1): 1-9.

Levels of allozyme variation are compared between a diploid invasive plant species, *Lonicera japonica* (2n = 18) and its polyploid native congener, *Lonicera sempervirens* (2n = 36) using 13 enzyme systems. Both are woody perennials and were sampled within the native range of *L. sempervirens* in south-eastern USA where *L. japonica* has been an invader since the late 19th century. Genetic structure and allozyme diversity were determined for nine and ten populations of *L. sempervirens* and *L. japonica*, respectively, from Georgia and South Carolina. Genetic variation within *L. japonica* is similar to that in other species with similar life history traits (percentage

polymorphic loci, $P_s = 75\%$; mean alleles per polymorphic locus, $A_p = 2.28$; total genetic diversity, $H_t = 0.216$). *L. sempervirens* has even higher genetic variation than *L. japonica* ($P_s = 91\%$; $A_p = 2.60$; and $H_t = 0.283$). Although both species have high levels of genetic diversity, this may be less important than their life history traits to their success in early successful habitats. However, establishment of a relationship between success in naturalization for woody perennials and levels of genetic diversity is hampered by the paucity of comparable records for other native:alien congeneric pairs.

(285) Record Schleicher, L. C. (1992). Efficacy and dissipation of pendimethalin and dithiopyr in a perennial ryegrass turf. *Agronomy*. Lincoln, Nebraska, University of Nebraska: 102.

(1250) Schouten, S. L. and N. H. Agnew (1994). Feeding the frenzy. *Am nurseryman* 180(5): 46-51.

(1007) Schuett, J. and J. E. Klett (1989). Preemergent weed control in container-grown herbaceous perennials. *Journal of Environmental Horticulture* 7(1): 14-16.
In trials during 1986-87, Surflan (oryzalin) at 2.24-6.72 kg a.i./ha, Ronstar (oxadiazon) at 4.48-13.44 kg and Rout (oxyfluorfen + oryzalin) at 3.36-10.08 kg were applied to container-grown *Ajuga reptans* [var.] *atropurpurea* (carpet bugle), *Campanula garganica* [var.] *major* (bellflower) and *Liatris spicata* (spike gayfeather) and Devrinol (napropamide) and Treslan (trifluralin) were each applied at 4.48, 8.96 and 13.44 kg to *Astilbe adensisii* (false spirea) and *Dicentra spectabilis* (bleeding heart). Weed control was acceptable with all herbicides except Surflan at 2.24 kg a.i. which did not control *Capsella bursa-pastoris*. Surflan at either 4.48 or 6.72 kg a.i. resulted in phytotoxicity of carpet bugle, while the 6.72 kg rate significantly reduced plant growth.

(1200) Scooco, C., C. Corti, et al. (1998). Introduction of *Amsonia tabernaemontana* Walt. in hilly area: germination test and first searches about the results in rutin. Proceedings of the symposium on plant biotechnology as a tool for the exploitation of mountain lands, Turin, Italy, 25-27 May 1997 No. 457: 357-362.
A. tabernaemontana is a perennial species from North America which contains a high concentration of rutin [rutioside] (4-5%). Seeds of

A. tabernaemontana are characterized by slow and uneven germination. Conditions promoting germination were investigated. The effects of GA3 (1 or 10 mM), immersion in tap water for 24 h and/or chilling for 3 days at 4°C on the germination of fresh and 1-year-old seeds obtained from 2 populations around Piacenza, Italy, were investigated. The best germination was observed in seeds treated with GA3 at 10 mM. The rutin content of 50 *A. tabernaemontana* plants grown for ornamental purposes was in the range 1.6-5.3% with an average of 3.5%.

(1118) Sedgley, M., E. G. Williams, et al. (1994). Self-incompatibility in woody horticultural species. Genetic control of self incompatibility and reproductive development in flowering plants (E.G. Williams, et al. (eds)) 141-163 (Advances in cellular and molecular biology of plants): vol. 2. Outbreeding is particularly prevalent among woody perennials and self incompatibility (SI) is only one of a number of mechanisms which promote cross pollination. Following an introduction where woody genera showing reduced seed set on selfing are tabulated, the subject is reviewed under the following headings: methodology; gametophytic SI; sporophytic SI; late-acting SI; interspecific incompatibility; overcoming incompatibility; and commercial considerations.

(290) Setyowati, N., L. A. Weston, et al. (1995). Evaluation of selected preemergence herbicides in field-grown landscape crops in Kentucky. *Journal of Environmental Horticulture* 13(4): 196-202. Research was conducted during 1990 and 1991 at the Horticultural Research Farm in Lexington, Kentucky, to evaluate the efficacy of herbicides available for use on woody landscape plants (simazine and oryzalin), newly labelled herbicides (isoxaben, isoxaben plus oryzalin, metolachlor and metolachlor plus simazine) and those not widely labelled for the nursery industry (oxyfluorfen and dithiopyr). Herbicide phytotoxicity was also evaluated in 10 species of woody nursery crops. Results 6 WAT (weeks after treatment) indicated that the standard of simazine at 1.1 kg ai/ha plus oryzalin at 3.3 kg ai/ha provided adequate control of most common broadleaf weeds (98%) and annual grasses (98%) but not yellow nutsedge (31%). Isoxaben plus oryzalin at 4.2 kg ai/ha (DF formulation) and isoxaben plus trifluralin at 4.2 kg ai/ha (granular formulation) gave excellent full-season control of nearly all broadleaf and grass

weeds with the exception of galinsoga and field bindweed. In addition, yellow nutsedge control was acceptable, ranging from 63 to 96% in these treatments. Isoxaben alone also provided excellent broadleaf control (93%) 6 WAT in 1990 but poorer (<70%) control of giant foxtail, galinsoga, and velvetleaf by 12 WAT. Dithiopyr (granular formulation) provided excellent full-season residual control of broadleaf weeds, nutsedge and grasses at the highest rate of 2.2 kg ai/ha. Oxyfluorfen at the higher rate (2.2 kg ai/ha) also controlled all species except yellow nutsedge. Poor broadleaf control was obtained 12 WAT with 3.3 kg ai/ha metolachlor or metolachlor plus simazine at rates up to 4.4 kg ai/ha in both 1990 and 1991. Pronamide at 2.2 kg ai/ha did not provide adequate control of either broadleaf or grasses at 6 or 12 WAT. No visible phytotoxicity to woody ornamentals was observed in either season up to 8 weeks after application. However, growth reductions were noted in both common lilac and red oak stem or trunk diameter following treatment with isoxaben at 1.1 kg ai/ha.

(1105)

Shetlar, D. J. and D. Herms (1997). Insect and mite control on woody ornamentals and herbaceous perennials. Columbus, Ohio, Ohio State University.

Abstract: Prepared to provide information on when, which insects and which stage of development, and how to safely and effectively control troublesome pests of landscape plants, this publication discusses pest control decision making, insecticides, protection, application equipment, integrated pest management (IPM). Includes list of top 25 nursery pests in Ohio, host/pest guide to insects and mites attacking ornamentals, and guide indicating suggested time to apply control measures based on seasonal appearance of specific pests.

(510)

Simms, C. (1996). Food of the Norse gods? Garden London 121(3): 124-125.

The Arctic raspberry, *Rubus arcticus*, is described for use in the garden, both for its fruits and its ornamental value. It is a low-growing, herbaceous perennial, reaching a height of 25-45 cm and spreading by underground shoots to form dense mats of bright green, trifoliate leaves. For commercial production, a sunny or slightly shaded site, sheltered from the wind, is recommended. Soil type is not critical, although very heavy, poorly drained soils and dry, sandy soils should be avoided. At least 2 cultivars are needed for cross

pollination, as the commonly available fruiting cultivars, Anna, Beata, Linda and Sofia, are self-sterile. Flowering takes place mainly in late May/early June and the main harvest time is around mid-July in the UK. By late Oct., plants begin to die back and produce a good show of autumn colour. The cultivar Valentina is best grown as an ornamental groundcover as it crops lightly.

(371)

Skroch, W. A., C. J. Catanzaro, et al. (1994). Preemergence herbicide evaluations on selected spring and summer flowering bulbs and perennials. *Journal of Environmental Horticulture* 12(2): 80-82.

Nine species of field-grown flowering bulbs and perennials were screened for tolerance to the preemergence herbicide products Dacthal (DCPA), Gallery (isoxaben), Pennant (metolachlor), PRE-M (pendimethalin), Stakeout (dithiopyr), Derby (metolachlor + simazine) and Snapshot (isoxaben + oryzalin). Herbicides were applied at recommended rates three to five times over two to three years. No detrimental effects on growth, development or flowering were observed. Most products controlled large crabgrass, horseweed and prostrate spurge. However, control of crabgrass and spurge was poor with Gallery at 0.84 kg ai/ha, and control of horseweed and spurge was poor with Dacthal.

(1113)

Skroch, W. A., C. J. Catanzaro, et al. (1994). Preemergence herbicide evaluations on selected spring and summer flowering bulbs and perennials. *Journal of Environmental Horticulture* 12(2): 80-82.

Field trials were conducted during 1990-1992 at Raleigh, on Cecil clay soil, to investigate the tolerance of 9 species of field-grown flowering bulbs and perennial ornamental plants (*Allium sphaerocephalon*, *Narcissus* X cv. Ice Follies, *Ornithogalum umbellatum*, *Canna* X cv. Firebird, *Crocsmia* X *crocsmiiflora* cv. Lucifer, *Hemerocallis* X cv. Pink Charm, *Iris* X *germanica* cv. Matinata, *Lilium* X cv. Sterling Star and *Paeonia* X cv. Sarah Bernhardt) to the preemergence herbicide products Dacthal (DCPA) [chlorthal-dimethyl], Gallery (isoxaben), Pennant (metolachlor), PRE-M (pendimethalin), Stakeout (dithiopyr), Derby (metolachlor + simazine) and Snapshot (isoxaben + oryzalin). Herbicides were applied at recommended rates three to five times over two to three years. No detrimental effects on growth, development or flowering were observed.

Most products controlled large crabgrass (*Digitaria sanguinalis*), horseweed (*Conyza canadensis*) and prostrate spurge (*Euphorbia humistrata*). However, control of crabgrass and spurge was poor with Gallery at 0.84 kg ai/ha, and control of horseweed and spurge was poor with Dacthal.

(328)

Skroch, W. A., C. J. Catanzaro, et al. (1990). Response of Nine Herbaceous Flowering Perennials to Selected Herbicides. *Journal of Environmental Horticulture* 8(1): 26-28. Nine herbicides registered for use on turf and ornamentals were applied semiannually for 2 years to 9 species of field grown herbaceous flowering perennials. The herbicides used were Balan (benefin), Betasan (bensulide), Dacthal (DCPA), Devrinol (napropamide), Fusilade (fluazifop), Ornamental Herbicide 2 (oxyfluorfen + pendimethalin), Pennant (metolachlor), Poast (sethoxydim), and Ronstar (oxadiazon). The perennial included fernleaf yarrow, shasta daisy, coreopsis, dianthus, daylily, candytuft, red hot poker, statice, and phlox. Betasan produced no visual phytotoxicity. All other treatments, excluding OH-2, caused less than 20% injury to all species tested. OH-2 caused 40%, 39%, and 30% injury to daylily, yarrow, and red hot poker, respectively. Economically tolerable (less than 25%) injury was exhibited by phlox and shasta daisy treated with OH-2, by daylily treated with Pennant, and by phlox treated with Ronstar. OH-2 increased flowering of coreopsis and statice by 97% and 235% respectively, while it reduced plant area of phlox by 53% and flowering of phlox by 34%. Both Pennant and OH-2 reduced flowering of dianthus by nearly 30%.

(1193)

Smith, D. B. and R. F. Davis (1986). Identification of cucumber mosaic virus from Vinca minor in New Jersey. *Plant Disease* 70(11): 1056-1059. Mild mosaic, chlorosis and distortion symptoms were observed on leaves of this perennial ground cover plant in Somerset, NJ. A virus isolated from these plants was identified as CMV based on host reactions, aphid transmissibility in a nonpersistent manner, icosahedral particle morphology, MW of 29 000 daltons of coat protein subunits, and serological relationships. This isolate is designated CMV-VI. Mouse ascites fluid produced to CMV-VI gave specific and sensitive reactions in ELISA and Ouchterlony gel double-diffusion tests. Field surveys indicated that CMV is present throughout New Jersey in *V. minor*.

(383)

Smith, E. M. and S. A. Treaster (1991). The effect of slow-release herbicide tablets on container-grown woody and herbaceous landscape crops. *Ornamental Plants. A Summary of Research*. Ohio State University(137): 1-5.

A study was conducted to evaluate the effectiveness of slow-release herbicide tablets of herbaceous and woody container-grown nursery stock. The tablets contained oxyfluorfen (Goal) at 0.5 lbs ai/A, metolachlor at 2.0 lbs ai/A and the surfactant Triton X-100 at 2% by volume. At 10 weeks, weed control was acceptable at 1 tablet/1 gal. container, 2 tablets/2 gal. container, 3 tablets/3gal. container, and 4 tablets/5 gal. container. One additional tablet/container increased weed control, but only slightly. Only Gold Flame spirea was injured among the seven herbaceous plants and 16 woody selections in the study. The larger tablet size, lower pressure and increased soluble herbicide (pennant) and surfactant concentrations combined to improve weed control over previous tablet evaluations.

(1150)

Smith, E. M. and S. A. Treaster (1992). Tolerance of herbaceous perennials to slow-release herbicide tablets. *Special Circular Ohio Agricultural Research and Development Center No. 140*: 9-13. A study was conducted to evaluate the efficacy of slow-release herbicide tablets for the control of bittercress [*Cardamine* sp.], crabgrass [*Digitaria* sp.], chickweed [*Cerastium* sp.], groundsel [*Senecio* sp.], oxalis [*Oxalis* sp.] and wild lettuce [*Lactuca* sp.] in 38 species and cultivars of container-grown herbaceous perennials. Tablets were blended with oxyfluorfen + metolachlor at 0.5 and 0.2 lb/acre, resp., and the surfactant Triton X-100 at 2% by vol., and application rates of 0, 2 and 3 tablets/2 gal container were used. Two tablets gave acceptable weed control for 10 weeks, and the addition of a 3rd tablet was not particularly beneficial. Slight phytotoxicity was evident on 6 species, and severe injury was observed on 2 species.

(1096)

Smith, E. M. and S. A. Treaster (1991). Composted municipal sludge from two Ohio cities for container-grown woody ornamentals. *OARDC Special Circular Ohio Agricultural Research and Development Center No. 137*: 22-24. Composted municipal sludge from Akron and Hamilton was used (1) at various rates in 14 different combinations of pine bark or hardwood

bark media, and (2) as a replacement for peat in different media. Two shrubs, *Rhododendron* cv. *Hershey Red* and *Euonymus fortunei* cv. *Emerald 'N Gold*, and one herbaceous perennial, *Rudbeckia [sullivantii]* cv. *Goldsturm*, were planted in containers on 18 May and growth (DW) records were taken on 4 Sep. The best growth of all 3 species was obtained in a 6:3:1 mixture of pine bark, Akron sludge and sand. Excellent growth was also observed in 6:1:2:1 and 6:2:1:1 mixtures of pine bark, Akron sludge, peat and sand. In general, plants grew better in media containing pine bark rather than hardwood bark. Amendment of media with sludge gave better growth than without sludge and a 10% supplement was as good as or better than 20 or 30%. Akron sludge replaced peat satisfactorily in pine bark media for *Euonymus* and *Rudbeckia*, but not *Rhododendron* which required a low pH. It could replace peat in hardwood bark media for *Rhododendron* and *Euonymus*, but not *Rudbeckia*. Hamilton sludge could not be used to replace peat in either pine bark or hardwood bark media. No phytotoxicity was observed with any sludge treatment.

(564)

Smith Jochum, C. and M. L. Albrecht (1988). Transplanting or seeding in raised beds aids field establishment of some Echinacea species. *HortScience* 23(6): 1004-1005.

In field trials, 3 *Echinacea* spp. (of medicinal interest and grown as cut flowers) were spring-raised by direct-seeding or transplanting seedlings into raised or flat beds. Plant height, leaf and flower numbers, and root and shoot DW were compared. Transplanting resulted in good establishment for all species, with no difference between bed type. *E. angustifolia* and *E. pallida* never emerged when direct-seeded on either bed type. Raised beds enhanced the establishment of direct-seeded *E. purpurea*. Compared with direct-seeding in flat beds, transplanting in raised or flat beds and direct-seeding in raised beds significantly increased root DW of *E. purpurea*.

(1251)

Smith, S. L. (1990). Everything's coming up natives. *American Nurseryman* 171(4): 68-83. Recommended species of trees, shrubs, herbaceous perennials and grasses native to the USA (and Canada in some cases) are listed for ornamental planting in particular situations.

(1069)

Smreciu, E. A., R. S. Currah, et al. (1988). Viability and germination of herbaceous perennial

species native to southern Alberta grasslands. *Can Field Nat* 102(1): 31-38.

The viability and germination of seed lots of 41 herbaceous perennial species native to southern Alberta grasslands were examined. The practical value of tetrazolium (TTC) and x-ray photography in screening seed lots for viability was evaluated. Although a reliable, rapid test for a few taxa, TTC often gave erratic results which were inconsistent with germination percentages and/or the physical condition of excised embryos. X-rays were useful for determining the percentage of full seeds in samples of species having large seeds, but had insufficient resolving power for samples of smaller seeds. Stratification improved germination in most species of Compositae, all three species of the Scrophulariaceae, and both species of Cactaceae. Scarification improved germination in 11 of 12 species of Leguminosae, and, in combination with stratification, improved germination of *Allium textile* (Prairie Onion) of the Liliaceae. Seeds of species in both Ranunculaceae and Rosaceae generally germinated as well with as without pre-treatment.

(1008)

Staats, D., D. Hillock, et al. (1998). Weed control and phytotoxicity of preemergence herbicides applied to container-grown herbaceous plants. *HortTechnology* 8(3): 325-328.

Five preemergence herbicides were applied to 7 herbaceous perennials to evaluate weed control and phytotoxicity. The species used during 1992 were *Rudbeckia fulgida* cv. *Goldstrum*, *Digitalis purpurea* cv. *Excelsior*, *Leucanthemum X superbum* cv. *Alaska*, *Stokesia laevis* cv. *Blue Danube* and *Geum quellyon* cv. *Mrs. Bradshaw*. The species used in 1993 were *Achillea tomentosa* and *Thymus pseudolanuginosus*. The same mixture of weed species (*Setaria glauca* [S. *pumila*], *Echinochloa crus-galli*, *Poa annua*, *Capsella bursa-pastoris*, *Senecio vulgaris* and *Amaranthus retroflexus*) was used both years. The herbicides and rates were napropamide (Devrinol 10G) at 4 and 8 lb a.i./acre; metolachlor (Pennant 5G) at 4 and 8 lb a.i./acre; oxyfluorfen + oryzalin (Row 3G) at 3 and 12 lb a.i./acre; trifluralin (Treflan 5G) at 4 and 8 lb a.i./acre; and oxadiazon (Ronstar 2G) at 4 and 8 lb a.i./acre. Plants were grown in no. 1 containers and weed seeds were sown onto the substrate surface. Two control treatments, no herbicides but with weeds (weedy control), and no weeds or herbicides (weed-free control) also were evaluated. Weed control was effective and similar for all herbicides tested. Napropamide at 8 lb a.i./acre caused stunting in *D. purpurea* (20-45%

less growth than the weed-free control).

Oxyfluorfen + oryzalin at 12 lb a.i./acre caused severe phytotoxicity (80-95% of plant injured) and stunted the growth (70-80% less growth, sometimes plant death) of *A. tomentosa*. *T. pseudolanuginosus* was stunted by all herbicides when applied at the recommended rates (42-97% less growth than controls) except for oxadiazon and oxyfluorfen + oryzalin. *T. pseudolanuginosus* appeared to be more susceptible to phytotoxicity than other species due to its less-vigorous growth habit and shallow, adventitious roots that were in contact with the herbicide.

(1125)

Staats, D. and J. E. Klett (1993). Evaluation of weed control and phytotoxicity of preemergence herbicides applied to container-grown herbaceous and woody plants. *Journal of Environmental Horticulture* 11(2): 78-80.

Six different pre-em. herbicides were used with 9 different plant species to evaluate weed control efficacy and possible phytotoxicity in pot experiments. The plant species tested were *Stachys byzantina*, *Campamila persicifolia*, *Achillea millefolium* cv. Summer Pastel, *Coreopsis lanceolata*, *Gypsophila pacifica*, *Wisteria sinensis*, *Syringa vulgaris*, *Phlox paniculata* and *Dahlia X hybrida*, all grown in a medium of clay loam soil, plaster sand and sphagnum peat (1:1:2 by vol.). The following herbicides were applied to the soil surface at 1X and 2X the respective recommended label rates: Pennant (metolachlor) at 4.6 and 9.1 kg/ha; Gallery 75DF (isoxaben) at 1.1 and 2.3 kg; Ronstar 2G (oxadiazon) at 4.5 and 9.0 kg; Rout 3G (oxyfluorfen + oryzalin) at 3.4, 6.8 and 13.6 kg; Surflan AS (oryzalin) at 2.3 and 4.6 kg; and Treflan 5G (trifluralin) at 4.5 and 9.0 kg. Weed seeds of *Setaria glauca* [*S. pumila*], *Echinochloa crus-galli*, *Poa annua*, *Capsella bursa-pastoris*, *Senecio vulgaris* and *Amaranthus retroflexus* were sown on the soil surface. Two control treatments (no herbicide and no weed seeds applied, or no herbicide but with weed seeds) also were evaluated. Weed counts at the end of the season indicated that Rout and Ronstar at both the 1X and 2X rates controlled >99% of the weeds (compared to the control treatment with weeds). Percentage weed control with the other herbicides were as follows: Surflan 1X = 92%, Surflan 2X = 95%, Pennant 1X = 93%, Pennant 2X = 98%, Gallery 1X = 35%, Gallery 2X = 43%, Treflan 1X = 88% and Treflan 2X = 96%. Evaluations also indicated that herbicides containing oryzalin resulted in phytotoxicity or stunting to *P. paniculata*, *G. pacifica* and *S. byzantina*. Gallery also resulted in

stunting in *S. byzantina*.

(1203)

Stanosz, G. R., M. F. Heimann, et al. (1997). Purple coneflower is a host of the aster yellows phytoplasma. *Plant Disease* 81(4): 424. The perennial purple coneflower (*Echinacea purpurea*) is native to open woods and prairies of the eastern USA and is gaining popularity as a garden and roadside ornamental. During late summer, 1996, 3 of 7 purple coneflower plants located in a residential garden in Dane County, Wisconsin, USA, exhibited symptoms associated with disease caused by phytoplasmas. Based on restriction fragment length polymorphism analysis of the PCR products, the associated phytoplasma was identified as phytoplasma 16S rRNA group I (aster yellows (AY) and related phytoplasmas), subgroup A. This is the first report of a host of the AY phytoplasma in the genus *Echinacea*.

(1220)

Starman, T. W., T. A. Cerny, et al. (1995). Productivity and profitability of some field-grown specialty cut flowers. *HortScience* 30(6): 1217-1220.

The productivity and profitability of annual and perennial field-grown specialty cut-flower species were evaluated for the southeastern USA. Data were collected on 20 annuals and 20 perennials in 1992 and on 19 annuals and 19 perennials (10 in their second year of production) in 1993. Productivity and profitability were based on yield and stem length measurements. Yield was expressed as total number of stems harvested. Income per 30-cm centre was predicted from the number of stems 41 cm long that were harvested. Some species had high yields but stem lengths that were too short for most market outlets. Among those species that combined high yield with long stems and resulted in high profitability without major pest or postharvest problems were the perennials *Achillea filipendulina*, *Echinacea purpurea*, *Liatris spicata* and *Platycodon grandiflorus* and the annuals *Antirrhinum majus*, *Cosmos bipinnatus*, *Scabiosa atropurpurea* and *Zinnia elegans*. The low overheads of field production coupled with productive species could prove to be profitable.

(1103)

Steiner, K. E. (1989). A new perennial *Nemesia* (Scrophulariaceae) from the western Cape. *South African Journal of Botany* 55(4): 405-408. A new and very distinctive species, *N. acornis*, endemic to the mountains around Pikeberg is

described. It is characterized by a perennial habit, ovate to widely ovate leaves with dentate margins, white flowers, and a short saccate spurless corolla tube with a prominent central invagination on the lower side.

(660)

Still, S. M. (1984). Perennial propagation [Herbaceous perennials, bulbs, division and cuttings, Chrysanthemums, daylilies, Siberian iris]. *Plants Gard Brooklyn Bot Gard Rec* 40(1): 26-34.

(1097)

Stimart, D. P. (1999). Development and integration of an instructional garden in education at the University of Wisconsin-Madison.

HortTechnology 9(4): 557-561.

The Allen Centennial Gardens are instructional gardens managed by the Department of Horticulture, University of Wisconsin-Madison. Twenty-two garden styles exist on the 2.5-acre (1.0-ha) campus site with a primary focus on herbaceous annual, biennial and perennial ornamental plants. The gardens are used for instruction mostly by the Department of Horticulture and secondly by departments of art, botany, entomology, landscape architecture, plant pathology, and soils. Class work sessions are limited due to the gardens' prominence on campus, high aesthetic standards, space restrictions, and large class sizes. Undergraduate students are the primary source of labor for plant propagation, installation and maintenance; management; and preparation of interpretive literature. Work experience at the gardens assists students with obtaining career advances in ornamental horticulture. Future challenges include initiating greater faculty use of the gardens for instruction and creating innovative ways to use the gardens to enhance instruction.

(1191)

Strefeler, M. S., E. Darms, et al. (1996). Isozyme characterization of genetic diversity in Minnesota populations of purple loosestrife, *Lythrum salicaria* (Lythraceae). *American Journal of Botany* 83(3): 265-273.

Starch gel electrophoresis of plant proteins was used to identify purple loosestrife (Lythrum spp.) cultivars and weedy populations. Preliminary determinations were made as to what degree weedy loosestrife populations were related (or genetically similar) to populations of L. alatum, L. virgatum and horticultural cultivars. Cluster analysis of the data indicated that native L. alatum was genetically different from all populations of

purple loosestrife and cultivars examined. The L. salicaria and L. virgatum cultivars, as groups, were not genetically distinguishable from the weedy populations analysed. Seven cultivars of L. salicaria origin analysed as a group were not distinguishable from the eight cultivars of L. virgatum origin, indicating that separation by cultivar origin may not be feasible. While the two "groups" were not distinguishable, most individual cultivars could be distinguished from one another by isozyme phenotype. Genetic variation was high within populations of weedy purple loosestrife but low among populations, which is characteristic of polyploid, perennial plant species that are widely distributed. Geographic location did not consistently correlate with genetic similarity.

(1247)

Strother, E. V. (1994). Marketing easy-care perennials and herbs. *Am nurserym* 179(1): 68-75.

(1128)

Svenson, S. E. (1994). Shading and pot color influence growth and flowering of strawberry firetails. *Proc annu meet Fla State Hort Soc* 106: 286-288.

Experiments were conducted to study the influence of shading and pot color on shoot growth of strawberry fire-tails (Acalypha hispiniolae. Urb.). Four mated liners with at least 13 cm stem length were potted in either green or white 20-cm hanging baskets filled with Pro-Mix BX. Ten days after potting, shoot tips were pinched leaving six nodes on each plant, and plants were fertilized with 12 g SierraBlen 18N-2.6P-1OK as a topdressing. Plants were grown under 60 or 80% shading with daily irrigation for 10 weeks. Flowers developing on stem tips were removed by hand once a week for 6 weeks following pinching. Stems of plants grown under 60% shade were 8, 9, and 12% longer 4, 6, and 10 weeks after pinching, respectively, compared to plants grown under 60% shade. Six weeks after pinching, stem lengths were 9% longer in plants grown in green pots compared to white pots. After 10 weeks growth, plants grown in green pots under 60% shading had 10% longer shoots, 10% more shoot dry weight and 23% larger flowers compared to plants grown in white pots under 60% shading. Strawberry firetails had 22% more shoot weight and 48% larger flowers when grown under 60% shading compared to 80% shading. Production using less than 60% shading may be beneficial, but light penetration through white pots may reduce growth and flowering with less shading.

(530)

Swanson, B. B. and J. B. Calkins (1994).
Herbicides for use on container grown woody
species and herbaceous perennials: 1993 - 1994.
1994 Nursery and Landscape Projects and
Programs. St. Paul, Minnesota: 195 - 206.

(528)

Swanson, B. T. and J. B. Calkins (1995).
Herbicides for use on container grown woody
species and herbaceous perennials: 1994 - 1995.
1995 Nursery and Landscape Projects and
Programs. St. Paul, MN, University of Minnesota:
222 - 236.

(529)

Swanson, B. T. and J. B. Calkins (1995).
Herbicides for use on container grown woody
species and herbaceous perennials: 1994 - 1995.
1994 Nursery and Landscape Projects and
Programs. St. Paul, MN, University of Minnesota:
207 - 221.

(1156)

Syrjanen, K. and K. Lehtila (1993). The cost of
reproduction in *Primula veris*: differences between
two adjacent populations. *Oikos* 67(3): 465-472.
The effect of flower and leaf removal on P. veris
was studied in 2 populations 800 m apart, one in a
grove of Corylus avellana bushes, the other in a
thicket of Populus tremula and Fraxinus excelsior
trees, on Seili Island in the southwestern
archipelago of Finland. Removal of flowers and
leaves resulted in decreased growth, flowering and
reproduction in the next 2 years in both
populations; there was not change in survival. In
one population, removal of all flowers increased
the flower number, the flower stalk length and the
leaf area, and doubled the seed set in the year
following the treatment. In the other population
flower removal slightly decreased the seed set in
the next year, while plant size did not differ from
the control group. There were no significant
differences in seed germinability between any of
the experimental groups. In a field test of seed
germination the seedlings of highly reproducing
individuals showed density-dependent mortality.
Two adjacent populations of the same species
responded differently to the manipulation of
reproduction. It was concluded that the
manipulation of reproduction may reveal the cost
of reproduction in perennial plants, and that
within-species variability offers an opportunity to
search for environmental conditions controlling
trade-offs.

(1197)

Takagi, H., K. Ikegami, et al. (1995). Substance
promoting germination and tube growth of
Polygonatum odoratum pollen. International
symposium on medicinal and aromatic plants,
XXIV international horticultural congress, Kyoto,
Japan 21-27 Aug No. 390: 153-160.
P. odoratum var. *pluriflorum* is a rhizomatous
perennial ornamental plant with medicinal
applications. In vitro germination of pollen grains
and pollen tube growth of *P. odoratum* were
enhanced on media containing a pistil, perianth or
pedicel. Analysis of extracts of floral parts
revealed that the active constituent was present in
the amphoteric and polar neutral fractions.
Addition of boric acid or calcium nitrate improved
germination a little. The optimum pH range for
germination was 4.7-6.1. Glutamic acid, aspartic
acid and cysteine also improved germination but
not pollen tube growth.

(637)

Taylor, R. D. (1990). Requirements and costs of
establishing and operating a three-acre herbaceous
perennial container nursery. Wooster, Ohio, The
Ohio State University, Ohio Agricultural Research
and Development Center, [1990] iii, 29 p. : ill.
This study identifies the resources and costs
associated with a herbaceous 3-acre perennial
nursery based on practices in USDA Plant
Hardiness Zones 5-6 in the north central region of
the USA and specific information from Ohio.
Calculations were based on 1989 prices. Five
groups of container-grown plants, differentiated by
cultural requirements were delineated. Grouping
was based on the combination of method of
propagation with length of production cycle.
Group I plants are seed-propagated, Group II
plants are cutting propagated, Group III plants are
propagated from crown divisions, Group IV:
garden chrysanthemums, from purchased rooted
cuttings, Group V: herbs, seed-propagated or
cutting propagated. Total costs per saleable plant
in one-quart containers were: \$1.17 for group I
plants, \$1.24 for group II plants and \$1.49 for
group III plants. For chrysanthemums, in three-
quart containers, these costs were \$1. Fixed costs
as a percentage of total plant costs were: 51%
48% 39% 44% and 54% for the 5 groups,
respectively. For all groups they averaged 49%.
Cost differences among groups were caused
primarily by cost of propagation materials, space
and overwintering requirements, and length of the
production cycle.

(623)

Taylor, R. D., E. M. Smith, et al. (1990). Production costs of operating a three-acre perennial container nursery in Ohio--1989. *Spec Circ Ohio Agric Res Dev Cent*(135): 9-13. Annual production costs of operating a three-acre perennial container nursery in Ohio were determined by synthesizing a model perennial container nursery using the conceptual framework of economic engineering. Annual production costs were about \$354 000 for the three-acre facility. Of the total, approximately \$172 000 (49%) were fixed costs and \$182 000 (51%) variable costs. The model nursery had capacity for annually producing approximately 180 000 (15 000 flats) saleable perennial plants in quart containers, 16 000 saleable chrysanthemums in three-quart containers, and 96 000 (6000 flats) saleable herbs in 16 flats.

(624)

Taylor, R. D., E. M. Smith, et al. (1990). Comparative costs of producing alternative plants in a three-acre perennial container nursery in Ohio--1989. *Spec Circ Ohio Agric Res Dev Cent*(135): 14-17.

The costs of producing container grown perennial plants in Ohio are compared, differentiated by plant group. Total annual costs per saleable plant in a three-acre perennial container nursery by plant group were \$1.17 per quart container (4 inches X 4 inches X 4 3/4 inches) for perennials propagated from seed, £1.24 per quart container for perennials propagated from cuttings, £1.49 per quart container for perennials propagated from crown divisions, \$1.95 per three-quart container for chrysanthemums, and \$0.99 per cell (16 cell/flat) for herbs, and averaged \$1.21 for all species. Fixed costs averaged 49% and variable costs 51% of the total.

(1079)

Taylor, R. D., E. M. Smith, et al. (1990). Comparative costs of producing alternative plants in a three-acre perennial container nursery in Ohio--1989. OARDC Special Circular Ohio Agricultural Research and Development Center No. 135: 14-17. The costs of producing container grown perennial plants in Ohio are compared, differentiated by plant group. Total annual costs per saleable plant in a three-acre perennial container nursery by plant group were \$1.17 per quart container (4 inches X 4 inches X 4 3/4 inches) for perennials propagated from seed, £1.24 per quart container for perennials propagated from cuttings, £1.49 per quart container for perennials propagated from crown divisions, \$1.95 per three-quart container

for chrysanthemums, and \$0.99 per cell (16 cell/flat) for herbs, and averaged \$1.21 for all species. Fixed costs averaged 49% and variable costs 51% of the total.

(622)

Taylor, R. D., E. M. Smith, et al. (1990). Physical facilities and capital requirements for establishing a three-acre perennial container nursery in Ohio--1989. *Spec Circ Ohio Agric Res Dev Cent*(135): 1-8.

Capital requirements for establishing a perennial container nursery in Ohio were about \$325 000 for a three-acre facility. This facility had 1.2 acres of growing space while buildings, roads, parking area, and other production facilities accounted for 1.8 acres. Of the total capital requirements, about \$37 000 (12%) was for bare land, \$32 000 (10%) for land improvements, \$158 000 (49%) for buildings, and \$98 000 (30%) for machinery and equipment.

(793)

Testezlaf, R., C. A. Larsen, et al. (1999). Tensiometric monitoring of container substrate moisture status. *HortTechnology* 9(1): 105-109. The objective of these experiments was to evaluate the use of tensiometers to monitor substrate moisture tensions for Metro-Mix 500 and 2 pine bark: 1 Canadian peat: 1 sand (PBPS, by volume) used for container-grown azalea (*Rhododendron indicum* cv. Mrs. G.G. Gerbing) and chrysanthemum (*Dendranthema grandiflora* cv. Coral Charm). Commercially available ceramic cups of 2 sizes, small (0.95 cm diameter and 2.86 cm long) and large (2.22 cm diameter and 7.62 cm long) were used to construct pressure transducer-equipped tensiometers. Data from these greenhouse experiments indicate that either the small or large ceramic cup could be used to monitor substrate tensions at which water would be available to container-grown plants.

(1163)

Thistlewood, H. M. A., J. H. Borden, et al. (1990). Seasonal abundance of the mullein bug, *Campylomma verbasci* (Meyer) (Heteroptera: Miridae), on apple and mullein in the Okanagan valley. *Canadian Entomologist* 122(11-12): 1045-1058.

The seasonal abundance of the mirid *Campylomma verbasci* was studied in and around 17 apple orchards in the Okanagan Valley of British Columbia during 1982-84. Apple and pear were overwintering hosts and the principal perennial hosts during the summer months. *C. verbasci* was

the most abundant mirid on apple and occurred in 16 orchards, with 2 or 3 generations per year. Nymphs first emerged from overwintered eggs near full bloom, but variation in timing occurred between orchards and years. Population densities of *C. verbasci* were higher in unsprayed than in sprayed orchards, but no differences were observed between commercial and 'organic' orchards. In June, some adults moved onto herbaceous plant hosts, primarily common mullein (*Verbascum thapsus*). Two generations of *C. verbasci* were found on mullein and the mirids were distributed in an aggregated pattern. Significant associations occurred among height, raceme length, or flower number of mullein plants and the number of individuals of *C. verbasci* on them. From mid-August to October, adult numbers declined on mullein and increased on apple. The number of mullein plants per orchard was not always associated with the density of overwintered individuals of *C. verbasci* in the following years.

(731)

Tyler, H. H., S. L. Warren, et al. (1996). Cyclic irrigation increases irrigation application efficiency and decreases ammonium losses. *Journal of Environmental Horticulture* 14(4): 194-198. Cyclic irrigation using pressure compensated drip emitters was evaluated for irrigation application efficiency, nutrient efficacy, and plant growth. The experiment, a RCBD with four replications was conducted in a simulated nursery using high volumes of irrigation which are common in container-grown ornamental nurseries in the southeastern United States. A container-grown plant production area, subdivided into 16 separate plots, allowed for the collection of all irrigation water leaving each plot. *Rudbeckia fulgida* cv. *Goldsturm* and *Cotoneaster dammeri* cv. *Skogholm* plants were potted into 3.8-litre containers in a pine bark:sand substrate (8:1 by vol) and irrigated with either 900 ml of water applied once a day, 450 ml applied in 2 cycles, 300 ml applied in 3 cycles, or 150 ml applied in 6 cycles. A cycle consisted of a 1-hour rest interval between each irrigation allotment. At 08.00 h daily, the volume of effluent from each plot was measured and a subsample of the effluent was analysed for NO₃-N, NH₄-N, and P. Cycled irrigation reduced the volume of effluent, increased irrigation application efficiency and decreased total NH₄-N losses compared with applying 900 ml once a day. There were no significant differences between cycled irrigation treatments in effluent volume or irrigation application efficiency. However, NH₄-N losses were greater when 450 ml was applied in 2

cycles than when 300 ml or 150 ml were applied in 3 or 6 cycles, respectively. Irrigation treatments did not affect NO₃ or P losses. Irrigation application efficiency over the course of the experiment averaged 0.52 for cyclic irrigation applications, a 38% improvement over the 900 ml standard application. Depending on irrigation treatment, 89-104% of the 3.0 g N applied was recovered. N efficiency averaged 89% and 88% for *C. dammeri* and *R. fulgida*, respectively. Of the 0.34 g P applied, 43.4% was recovered. P efficiency averaged 29% for both species. Growth, nutrient concentration, and nutrient content were not affected by irrigation treatments in either species.

(1234)

Uhlinger, R. D. (1982). Wide crosses in herbaceous perennials. *HortScience* 17(4): 570-574.

The following topics are reviewed with reference to wide crosses: (1) objectives, (2) problems (including biochemical/genetic barriers), (3) measures to achieve success (including chemical aids, morphological manipulation, natural synergists, in vitro pollination, changing parental ploidy, embryo culture and rendering the hybrids polyploid), (4) products, (5) the justification for investment and (6) constraints on wide-crossing programmes. Many of the references refer to crop plants.

(1252)

Uhlinger, R. D., D. S. Nuland, et al. (1974). Perennial flowers and ground cover for Nebraska. Agricultural Experiment Station, Nebraska University No. SB 531: 15 pp. Seventeen recommended ornamentals are listed, with details of their growth and flowering, on the basis of results of 3 years' observation trials on commercial stocks grown at 3 sites.

(658)

Urbano, C. C. (1986). Perennial interest in sun or shade three seasons of the year. *Am Nurseryman* 164(10): 41-44.

(1102)

VanDerZanden, A. M. and T. Cook (1999). A multifunctional horticulture teaching garden at Oregon State University. *HortTechnology* 9(4): 549-551.

Once an abandoned property at the edge of campus, the 7,000 ft² (650.3 m²) horticulture teaching garden at Oregon State University has evolved from an overgrown residential lot into a

well-defined and meticulously maintained garden. Since its beginning, an irrigation system, hardscapes, turf, bulbs, annuals, perennials, and woody plants have been installed by students enrolled in undergraduate horticulture courses. About 200 students use the garden annually as part of their formal instruction and it is currently integrated into the curricula of courses in landscape design, landscape construction and maintenance, and herbaceous and woody plant identification. Because the garden space is dynamic, curriculum changes can easily be accommodated.

(1192)

Vanstone, D. E., W. G. Ronald, et al. (1982). Nursery propagation of woody and herbaceous perennials for the Prairie Provinces. Publication, Agriculture Canada No.1733E: 51 pp. This publication outlines procedures for propagating nursery-grown trees, shrubs, ground covers and herbaceous perennials on a commercial scale. A general section on procedures for propagation is followed by specific sections outlining technical details for each kind of plant. The publication should serve as a practical manual for nursery growers.

(496)

Visser, C., J. A. Qureshi, et al. (1992). Morphoregulatory role of thidiazuron. Substitution of auxin and cytokinin requirement for the induction of somatic embryogenesis in geranium hypocotyl cultures. *Plant Physiology* 99(4): 1704-1707. Somatic embryogenesis was induced in hypocotyl explants of *Pelargonium X hortorum* cv. Scarlet Orbit Improved cultured on MS medium supplemented with various concentrations of thidiazuron (TDZ). Within 2 weeks, somatic embryos were observed in treatments containing TDZ at 0.2-1.0 μ M. The use of BA in combination with IAA also resulted in embryogenesis, but at a significantly lower rate than that obtained with TDZ. Hypocotyl culture for only 2 days on TDZ-supplemented medium before transfer to growth-regulator free medium was sufficient to induce somatic embryogenesis. This distinction between the induction and expression of embryogenesis may provide an experimental system for studying the developmental biology of somatic embryogenesis. Substitution of the auxin-cytokinin requirement by TDZ suggests the possibility of a novel mode of its action by modulation of endogenous growth regulators.

(1225)

Vrugtman, F. (1990). Directory of International Registration Authorities for cultivar names. *HortScience* 25(6): 618-621.

The current list of international registration authorities for ornamental plants is given. These are generally societies or institutions who, in turn, appoint a registrar. The directory lists taxa from *Acacia* to *Zigadenus* but does not include individual Australian genera (except *Leptospermum*, *Rhododendron* and those in the *Orchidaceae*), certain hardy herbaceous perennials and other undesigned woody plant genera for whom registrars are noted.

(1155)

Waser, N. M. and M. V. Price (1993). Crossing distance effects on prezygotic performance in plants: an argument for female choice. *Oikos* 68(2): 303-308.

Seed set in the perennial larkspur *Delphinium nelsonii* is greater in crosses between plants growing an intermediate distance apart than in shorter and longer crosses. Since crossing distance is an attribute of a specific combination of parents, its effect on seed set represents an interaction of these parents, and since genetic similarity declines with physical distance in *D. nelsonii* populations, the interaction reflects parental genetic similarity. Understanding processes responsible for the effect is simplified if seed set differences result from prezygotic events, because in this case no inbreeding or outbreeding depression are involved. In 1990 pollen tubes were examined after performing crosses between plants separated by 1, 10 or 100 m. The 10 m crosses delivered the most tubes to the ovary. A combined analysis of the 1990 experiment and three earlier experiments showed that this prezygotic difference in performance is significant and of the same magnitude as seed set differences. Disproportionate failure of pollen tubes in 1 and 100 m crosses reflects a trait of the maternal parent rather than of pollen, because the kinship of haploid pollen to a zygote it has fertilized always exceeds maternal kinship to that zygote. Thus the conditions for pollen suicide to evolve by natural selection are more restrictive than those for female choice to evolve, and the latter is more likely to control the outcome of the parental interaction.

(1206)

Welker, W. V., Jr. and D. L. Peterson (1987). A rotary herbicide wiper for postemergence weed control in perennial horticultural crops. *Weed Technology* 1(4): 319-322.

A rotary wiper developed to apply herbicides selectively to weeds beneath horticultural crops such as fruit trees and ornamentals is described. Herbicide is delivered internally through a circular pipe manifold imbedded in a rotary polyurethane foam disc, thus avoiding herbicide drift. A free-wheeling bumper wheel, larger than the wiper disc, is mounted just above the disc causing it to move around a tree trunk or shrub on contact. The rotary wiper effectively applied herbicides to weeds within the tree row.

(129)

Whalley, D. N. (1974). Nutrition of hardy ornamental nursery stock. [Fertilizers, cultivation]. ADAS Q. Rev. 13: 27-41.

A review based mainly on literature from the last two decades, designed to provide information on the application of fertilizers and requirements for optimum growth and development, in view of the growing importance of woody perennials for amenity planting in both the public and private sectors. The paper is arranged under the headings: Absorption and translocation of nutrients; comparisons with fruit crop requirements; Requirements of forest trees and nursery stock crops; Leaf analysis determination; Effects of nutrition on growth (including a section on calcifuge plants); Container growing; and Timing of fertilizer applications.

(1209)

Whitcomb, C. E. (1972). Influence of tree root competition on growth response of four cool season turfgrasses. *Agron J* 64(3): 355-359. Tree roots reduced the growth and vigour of most grasses even when water and nutrients were maintained at optimum levels. The presence of roots of *Acer saccharinum* or *Gleditsia triacanthos*, however, appeared to have no effect on the growth of *Festuca rubra* and *Poa trivialis* turf, although *P. trivialis* plants in the vicinity of tree roots later became diseased. *Poa pratensis* top growth was the most affected by tree roots; that of perennial ryegrass (*Lolium perenne*) slightly less so.

(1083)

Whittall, J., A. Liston, et al. (2000). Detecting nucleotide additivity from direct sequences is a SNAP: an example from *Sidalcea* (Malvaceae). *Plant Biology* 2(2): 211-217. Superimposed nucleotide additivity patterns (SNAPs) were detected from direct sequences of

the nuclear ribosomal DNA internal transcribed spacers in a complex of perennial *Sidalcea* species from the Pacific Northwest of the United States. Although only 2.8% sequence variation exists among the eight ITS accessions, parsimony analysis identified two distinct lineages within this complex consistent with known ploidy levels. Six SNAPs were identified in a known tetraploid *S. virgata*, suggesting allopolyploid origins from diploid *S. virgata* and one of two hexaploid *Sidalcea* species. A dosage effect detected at all six SNAP sites is consistent with the unequal sized parental genomes of allopolyploid *S. virgata*.

(1114)

Whitwell, T. and J. Kelly (1989). Effects of preemergence herbicides on hosta and daylily. *Journal of Environmental Horticulture* 7(1): 29-31. Thirteen pre-em. herbicides were evaluated for phytotoxicity to container grown hosta (*Hosta* spp.) cv. *Hyacinthina* and daylily (*Heimerocallis* spp.) cv. *Sammy Russell*. Severe injury (28-55%) was observed from Ronstar (oxadiazon) and Goal (oxyfluorfen) for both species. The other herbicides did not cause visual injury. Surflan (oryzalin), Endurance (prodiamine) and Pennant (metolachlor), were selected to investigate plant tolerance in field plantings at 1.1, 2.2 and 4.5 kg/ha. None of these herbicides caused visual injury or reduced shoot or root wt for 60 or 90 days after treatment. Daylily flower number was not affected by any of the herbicide treatments.

(630)

Wilson, S. B., Rajapakse, et al. (2000). Media composition and light affect storability and poststorage recovery of micropropagated hosta plantlets. *HortScience* 35(6): 1159 - 1162. Hosta (*Hosta tokudama* Makeawa 'Newberry Gold') plantlets were micro. propagated photoautotrophically (without sucrose in medium) or photomixotrophically (with 2% sucrose in medium) for 3 weeks at 23°C under 80 micromol $m^{-2} s^{-1}$ photosynthetic photon flux (PPF) prior to long-term storage. Plantlets were stored for 4, 8, or 12 weeks at 5, 10, or 22°C in darkness or under white (400 - 800nm), blue (400 - 500 nm), or red (600 - 700 nm) light at or near light compensation points. Illumination during storage was necessary to maintain dry weight and regrowth potentials of plantlets in vitro, but light quality had no effect on these parameters. All photoautotrophic plantlets stored in darkness were of poor quality at the time of removal from storage and died when transferred to the greenhouse. Dark-stored photomixotrophic

plantlets survived storage for 12 weeks at 5°C, but declined in appearance (visual quality) as the storage duration increased. Decline in visual quality was greater when plantlets were stored at 10 and 22°C. Leaf dry weight of illuminated plantlets increased and percentage of leaf yellowing decreased as storage temperature increased. Recovery of illuminated plantlets from photomixotrophic storage was best when plantlets were stored at 22°C. These plantlets were characterized by increased visual quality (color and form) and increased dry weight compared with those in other treatments. After 60 days in the greenhouse, the dry weight of these plantlets was similar for 4-, 8-, and 12-week storage durations, indicating flexibility in storage time if specific light and temperature provisions are met.

(1173)

Wisniewski, M., T. J. Close, et al. (1996). Seasonal patterns of dehydrins and 70-kDa heat-shock proteins in bark tissues of eight species of woody plants. *Physiologia Plantarum* 96(3): 496-505. Although considerable effort has been directed at identifying and understanding the function and regulation of stress-induced proteins in herbaceous plants, reports concerning woody plants are limited. Studies with herbaceous crops have revealed similarities in the types of proteins that accumulate in response to a wide array of abiotic stresses and hormonal cues such as the accumulation of abscisic acid. Many of the identified proteins appear to be related to dehydrins (the D-11 subgroup of late-embryogenesis-abundant proteins). Seasonal induction of dehydrins and seasonal patterns of other stress-induced proteins were examined in woody plants. Bark tissues from 8 woody plant species (peaches cv. Loring, apples cv. Golden Delicious, thornless blackberry cv. Chester, *Populus nigra*, *Salix babylonica*, *Cornus florida*, *Sassafras albidum* and *Robinia pseudo-acacia*) were collected monthly for a period of 1.5 years. Immunoblots of bark proteins were probed with a polyclonal antibody recognizing a conserved region of dehydrin proteins, and monoclonal antibodies directed against members of the HS70 family of heat-shock proteins. Some proteins, immunologically related to dehydrins, appeared to be constitutive; however, distinct seasonal patterns associated with winter acclimatization were also observed in all species. The molecular masses of these proteins varied widely, although similarities were observed in related species (*S. babylonica* and *P. nigra*). Identification of proteins using the monoclonal antibodies (HSP70, HSC70, BiP) was

more definitive because of their inherent specificity, but seasonal patterns were more variable among the 8 species examined. This study represents only a precursory examination of several proteins reported to be stress related in herbaceous plants, but the results indicate that these proteins are also common to woody plants and that further research to characterize their regulation and function in relation to stress adaptation and the perennial life cycle of woody plants is warranted.

(1162)

Wolf, P. G. and P. S. Soltis (1992). Estimates of gene flow among populations, geographic races, and species in the *Ipomopsis aggregata* complex. *Genetics* 130(3): 639-647. Interpopulation gene flow within a species can reduce population differentiation due to genetic drift and genetic exchange among taxa can impede speciation. Allozyme data was used to estimate gene flow within and among geographic races and species of perennial herbs in the *I. aggregata* complex (Polemoniaceae). Estimates of interpopulational gene flow within taxa from two methods (F statistics and private alleles) were correlated with one another. Gene flow among populations within each geographic race (subspecies) of *I. aggregata* was relatively high (N_m (average number of individuals per generation migrating between populations) > 1.0). Gene flow was also high among populations of *I. arizonica* and among four northern populations of *I. tenuituba*. However, gene flow was low ($N_m < 1.0$) for *I. tenuituba* when a population representing subsp. *macrosiphon* was included. This is consistent with previous findings that subsp. *macrosiphon* has had an independent origin and is reproductively, as well as geographically, isolated. A recently developed model, based on hierarchical F statistics, was employed to estimate genetic exchange among taxa. Gene flow estimates were generally high among races of *I. aggregata* ($dN_{mrace} > 1.0$) but were low among subspecies of *I. tenuituba* ($dN_{mrace} < 1.0$). Consistent with morphological evidence, estimates of interspecific gene flow were moderate between *I. aggregata* and *I. tenuituba*, which hybridize in several areas. However, contrary to morphological evidence, relatively high levels of interspecific gene flow involving *I. arizonica* were estimated. Results suggest that *I. arizonica* has hybridized with other species without the transfer of morphological traits. In the *I. aggregata* complex, gene flow appears to be an important evolutionary force shaping geographic

variation for allozymes within species, but is insufficient to prevent morphological divergence among taxa.

(1228)

Yuan, M., W. H. Carlson, et al. (1998). Effect of forcing temperature on time to flower of *Coreopsis grandiflora*, *Gaillardia X grandiflora*, *Leucanthemum X superbum*, and *Rudbeckia fulgida*. *HortScience* 33(4): 663-667.

The effects of temperature on time to flower and plant appearance were investigated in plants of field-grown, bare-root *C. grandiflora* cv. Sunray, *G. grandiflora* [*G. aristata*] cv. Goblin and *R. fulgida* Goldsturm, and in tissue culture-propagated *L. superbum* cv. Snowcap. Plants were exposed to 5°C for 10 weeks, and were then grown in greenhouse sections set at 15, 18, 21, 24 or 27° under 4-h night-interruption lighting until anthesis. Days to visible bud (VB), days to anthesis (FLW), and days from VB to FLW decreased as temperature increased. The rate of progress toward FLW increased linearly with temperature, and base temperatures and degree-days of each developmental stage were calculated. For *C. grandiflora*, *L. superbum* and *R. fulgida*, flower size, flower-bud number, and plant height decreased as temperature increased from 15 to 26°.

(1226)

Zhang, D., A. M. Armitage, et al. (1995). Environmental control of flowering and growth of *Lysimachia congestiflora* Hemsl. *HortScience* 30(1): 62-64.

L. congestiflora (dense-flowered loosestrife) has recently been grown commercially in the USA and is marketed as a bedding plant and hanging-basket plant in the north and as a half-hardy perennial in the south. *L. congestiflora* is a quantitative long-day (LD) plant. Plants given a LD photoperiod (16 h) flowered 21 and 34 days earlier than plants given 12- and 8-h photoperiods, respectively. Plants under LDs produced significantly more flowers than those under 8- and 12-h photoperiods. Only 1 week of LD was needed for 100% flowering; however, optimum flower count and size were produced with 3 weeks of LD. Plant DW did not differ significantly among treatments; however, LDs produced fewer but larger leaves, particularly those subtending the inflorescence. Total plant growth increased as temperature increased. Low temperature (10°C) decreased flower initiation and prevented flower development, while high temperature (26°) reduced the persistence of open flowers. The optimum temperature for dense-

flowered loosestrife growth was 20°. Flowering was accelerated and DW production increased as irradiance levels increased from 100 to 300 μmol m⁻² s⁻¹.

(1078)

Zimmerman, R. H. (1996). Commercial application of tissue culture to horticultural crops in the United States. *Journal of the Korean Society of Horticulture Science* 37(3): 486 - 490.

Commercial micropropagation (of orchids) started in the USA in 1965. The historical background of micropropagation in the USA, a description of the industry and the production of micropropagated plants (including foliage plants, fruit, ornamental and forest species, herbaceous perennial plants, and vegetables) in the USA are described.

D. Extension Activities

Information from this project was presented at the Alberta Horticultural Congress, November 2000. The Saskatchewan Nursery Trades Association is now an affiliate member of Landscape Alberta and Nursery Trades Association and many of the SNTA members regularly attend this conference.

E. Further Development

While a lot was accomplished with this project, more effort is required on developing a quick, easy and accurate method to evaluate fertility status of containers throughout the season. Results should be easily understood together with clear indications of action. Also, nitrogen source should be evaluated using a wider of plant material to determine if the response that we observed in this study is species specific. Finally, while we were able to satisfactorily conclude that container size did not severely impact winter survival, it would be useful to evaluate fungicide treatments on survival on some of the more disease-susceptible species such as *Lamium* and *Gentiana*.

F. Personnel

Erl Svendsen (BSc) was hired to manage all aspects of this project.

G. Equipment

No equipment worth > \$500 was purchased for this project.